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Forest Area Estimates from Landsat MSS and Forest Inventory Plot Data

Richard A. Birdsey, W. Frank Miller, Jon Clark, and Robert H. Smith

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SUMMARY

Forest area estimates for Puerto Rico from Landsat multispectral scanner data were compared with area estimates derived from black and white aerial photographs. Area estimates were adjusted according to a field check at 141 sample plot locations. Adjusted Landsat area estimates differed from adjusted photo area estimates by 1.7 percent. The sampling error for Landsat data was nearly twice the sampling error for photo-interpreted data.

Forest Area Estimates from Landsat MSS and Forest Inventory Plot Data

Richard A. Birdsey, W. Frank Miller, Jon Clark,
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INTRODUCTION

Forest area estimates are used worldwide for resource evaluation, monitoring, and planning. Recent concern about deforestation in the tropics has revealed the lack of current, reliable forest area estimates in many developing countries (UNESCO 1978). Many countries do not have the financial and technical resources at hand to conduct large scale forest inventories.

Landsat multispectral scanner (mss) data has, in recent years, been considered for its potential contribution to forest resource evaluation. Computer-processed satellite data can be substituted for data previously obtained from time-consuming photo interpretation. A recent study has documented the feasibility of applying Landsat technology to forest inventory (Nelson and Hoffer 1979). Landsat imagery has been used in the tropics to monitor forest cover alteration (Williams and Miller 1979), and in Costa Rica, Landsat data was incorporated into a geographic data base to develop cover type estimates for resource analysis (Sader 1980). In the most recent World Forest Inventory, visually-interpreted Landsat images were the only sources of information for some remote regions in Latin America (Lanly et al. 1982).

In general, the most successful projects have combined Landsat with ground truth or other geographic information. Some studies have explored the possibility of merging Landsat data with forest survey field data gathered by the U.S. Forest Service (Langley et al. 1980; Mroczynski et al. 1980). These pilot studies have established the feasibility of incorporating Landsat data into a sampling framework and demonstrated the usefulness of a geographic information system for accurately registering forest survey plot data with the Landsat data.

This study was initiated after a recent inventory of Puerto Rico highlighted the limitations of existing aerial photography (Birdsey and Weaver 1982). The inventory data was used to assess the potential benefits from combining Landsat data with forest survey data in Puerto Rico.

OBJECTIVES

The project goal was to develop rapid, efficient survey techniques for mountainous tropical regions. Specific objectives were:

1. Develop an area stratification based on terrain and Holdridge's ecological life zones (Holdridge 1969).
2. Compare forest area estimates from Landsat data with estimates from black and white aerial photography.
3. Evaluate potential benefits from combining Landsat data with forest survey data.
4. Explore usefulness of a geographical data base for combining the various data sources.

STUDY AREA

A search for Landsat data covering Puerto Rico found only one usable scene with cloud-free coverage of the northwestern third of Puerto Rico (fig. 1). Two ecological life zones account for most of the area: the subtropical moist forest zone receives between 1,000 and 2,000 mm of annual rainfall, and the subtropical wet forest zone receives between 2,000 and 4,000 mm of annual rainfall (fig. 2). Mean annual biotemperature ranges from 18° to 24° C.

The moist forest zone includes the coastal plain, interior valleys, and a wide band of limestone hills. Crops, pasture, and urban land uses are common in the plains, valleys, and lower slopes. Secondary forests are developing on the less productive, steeper slopes which are no longer farmed. Portions of the limestone hills are virtually inaccessible due to extremely rugged topography. The hills support a complex forest vegetation on varied slope positions. Tall forests in the sinkholes, bottoms, and lower slopes grade into scrub vegetation or bare soil on the xeric upper slopes, ridges, and cliff faces. Steep, forested slopes, sensitive to disturbance, have little commercial forest management potential.

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The wet forest zone includes most of the higher, wetter sites in the central mountains. Active and abandoned coffee plantations are common, interspersed with pasture, cropland, and secondary forest. The steep slopes and high rainfall quickly cause soil erosion and reduced soil productivity when the land is cultivated. Coffee grown under shade trees reduces the exposure of bare soil to intense storms. A portion of this life zone receives high rainfall (more than 2,500 mm/year) on slopes greater than 60 percent. Some forested areas are critical water catchments and should remain under protective forest cover.

METHODS

Forest Survey

An initial estimate of forest area was made from a dot-count on black and white 1:20,000 aerial photographs taken in 1977. Forest area estimates obtained from the dot-count were adjusted according to a ground check of land use at each sample location. Data on species composition and timber volume were obtained by establishing permanent sample plots at all forested sample locations. A detailed site description was made for each forested location. Fieldwork was done in 1980 and included land cover checks at 437 locations.

Landsat Image Processing

The Landsat scene was processed at the Mississippi Remote Sensing Center (Miller et al. 1982). The digital Landsat data were classified using a technique which combined elements of both supervised and unsupervised classification procedures. This technique consisted of selecting several training fields from the study area, with each field including a dominant cover type and a variety of other cover conditions. Statistics (reflectance values) from each training field were pooled for clustering into spectrally similar classes (Lockheed Engineering Co. 1977). Clusters were then assigned cover classes based on ancillary information, including panchromatic 1:20,000 stereo aerial photographs, topographic quadrangle maps, half of the ground truth information from the 1980 forest survey, and some additional field observations. Once the clusters were assigned the appropriate cover classes, the entire scene was classified using the maximum likelihood approach.

Prior to image processing, the survey area was stratified into two regions using the life zone classification. The two life zones have different land use patterns and produce different spectral responses in similar vegetation. In order to improve classification accuracy, each life zone had to be classified separately. To accomplish this, the entire scene was classified twice using unique sets of training statistics from each life zone. Only data which fell inside the life zone from which the statistics were taken was valid.

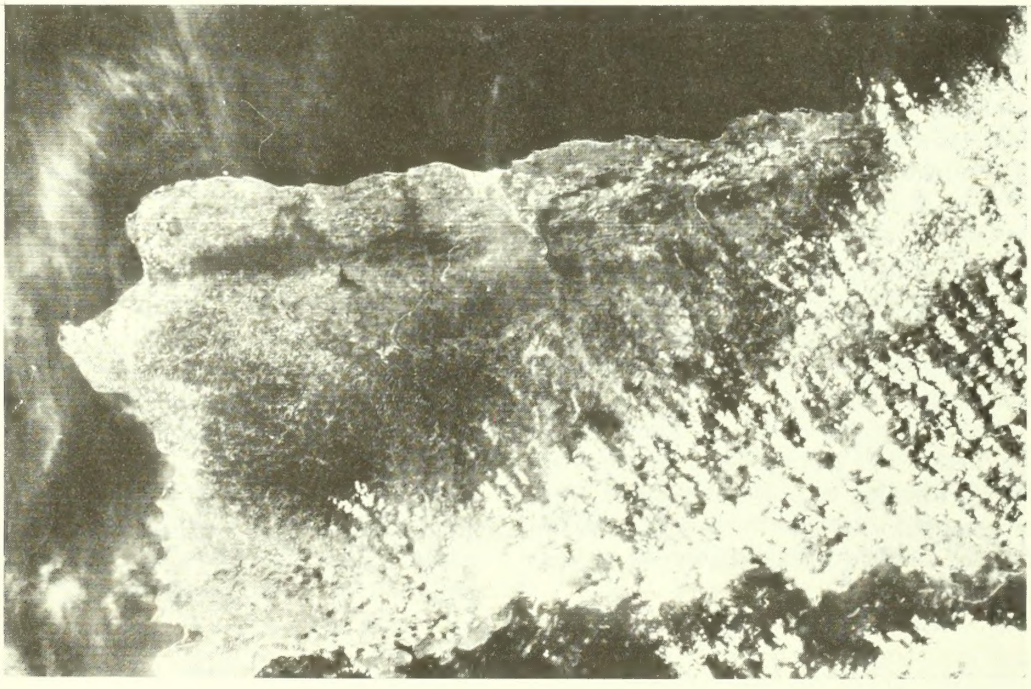

Figure 1.—*Landsat MSS coverage and atmospheric conditions, Western Puerto Rico, March 30, 1978.*

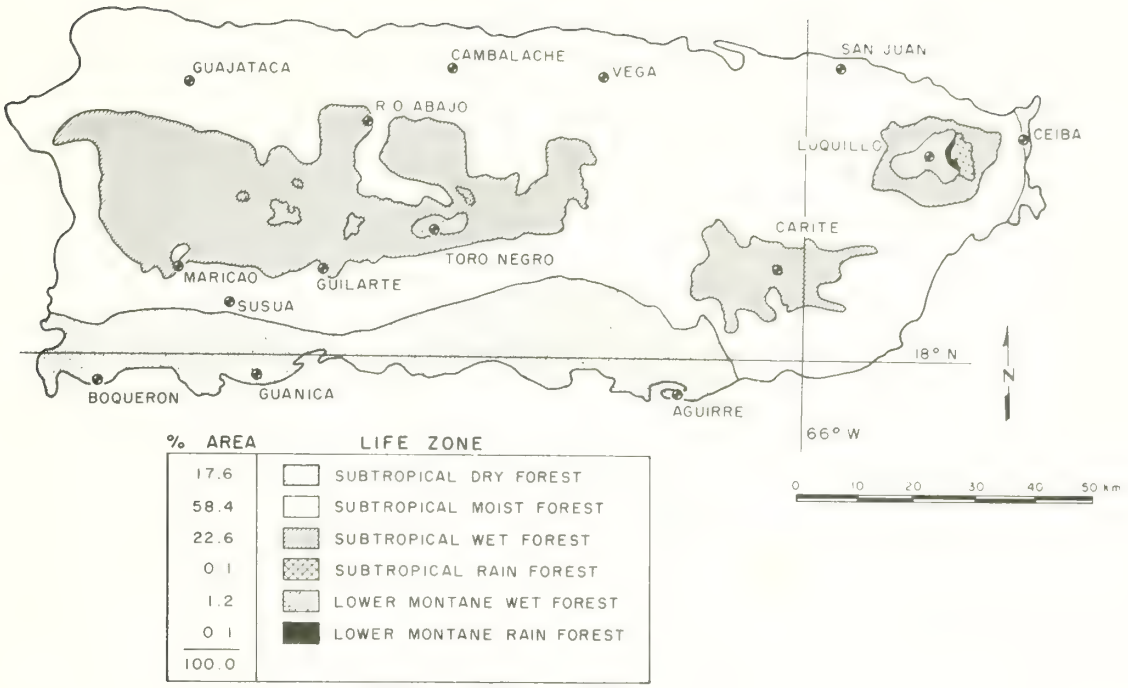

Figure 2.—*Ecological life zones of Puerto Rico.*

In order to stratify the Landsat data, classify each stratum separately, recombine the strata into a single product, and make use of ancillary data, a geographic data base was constructed. The data base employed a grid or cell-based system and an arbitrary set of coordinates. The data base allowed access of all data types or classes from one cell, or a group of cells, simultaneously.

A visual interpretation of a black and white print of the Landsat data revealed the presence of variable atmospheric haze over the study area. Reflectance values were elevated in the haze regions to an extent that varied with the density of the haze. In order to eliminate classification errors due to haze, only the haze-free portion of the Landsat scene was used in this analysis. The haze region was delineated on a 1:250,000 scale print of the data, then digitized and added to the data base.

Merging the Data

The two classified Landsat data sets, digitized life zone boundaries, and the digitized haze boundaries were input to the data base for merging. By using the life zone map as a mask, the valid portion of each classification was extracted and the two portions were merged to produce one valid land cover map.

Each forest survey plot location was digitized within a particular 4-ha cover type cell (fig. 3). The 4-ha resolution ensured that most plots were correctly registered within the identified cover type cell. The Landsat classification results were treated as an initial estimate of forest area, just as the aerial photos provided an initial estimate of area for the forest survey. The Landsat estimate was then adjusted according to actual ground cover at the forest survey plot locations. The adjusted estimate explains misclassified data cells and changes in land use between the date of image acquisition and the collection of ground truth. Sampling errors were estimated using random sampling formulae, as in the forest survey.

RESULTS

To allow fair comparison of the three area estimation procedures, the region covered by atmospheric haze in the cloud-free portion of the Landsat scene was eliminated from the study area, leaving 205,000 ha or 23 percent of the land area of Puerto Rico. This area included 141 field plot locations from the forest survey for ground truth.

Forest Survey

Area estimates based on 1980 forest survey data were computed for the haze-free portion of the study area for each of the two life zones (table 1). A total of 5160 photographic classifications were made, and 141 sample locations were visited in the field. The

adjusted proportion of forest area for the moist forest zone was 31 percent, and for the wet forest zone, 52 percent.

These area estimates can be further subdivided by land use categories based on photo and field observations (table 2). Results are similar to area estimates for the whole island since the study area represents the range of conditions found in Puerto Rico, excluding the dry southern coast. Forest cover is more prevalent in the wet forest zone, especially active and abandoned coffee shade. Nonforest land uses occupy more than two-thirds of the moist forest zone, with pasture and cropland together occupying 57 percent of all land.

Table 1.—*Forest cover estimates for the haze-free study area from 1980 survey data*

Forest life zone	Total area	Proportion of forest land		Sampling error[1]
		Unadjusted	Adjusted	
	hectares	*percent*		
Moist	122,484	51.9	30.5	3.1
Wet	82,888	71.9	52.1	3.7
Total	205,372	60.4	39.2	

[1]By random-sampling formula, 67 percent probability level.

The proportion of photo misclassification exceeded 25 percent for each life zone (table 3). In the moist forest zone nearly all misclassifications were due to difficulty in distinguishing forest from pasture in transition areas where trees and shrubs begin encroachment. Because of shadows and poor photography, pasture often appeared as non-stocked or young secondary forest.

In the wet forest zone, misclassification occurred when bananas, bamboo, fruit trees, and other vegetation common to rural residences appeared as forest in the photographs. Some plots were misclassified due to the presence of a new "shadeless" coffee variety. Land clearing between the photography date and the fieldwork also contributed to misclassifications. A land classification scheme which could yield better results with black and white photography has been developed (table 4).

Landsat Classification

Uncorrected Landsat forest area estimates for the haze-free region were similar to unadjusted forest survey estimates in both life zones (table 5). Active and abandoned coffee shade could not be distinguished from secondary forests; however, several

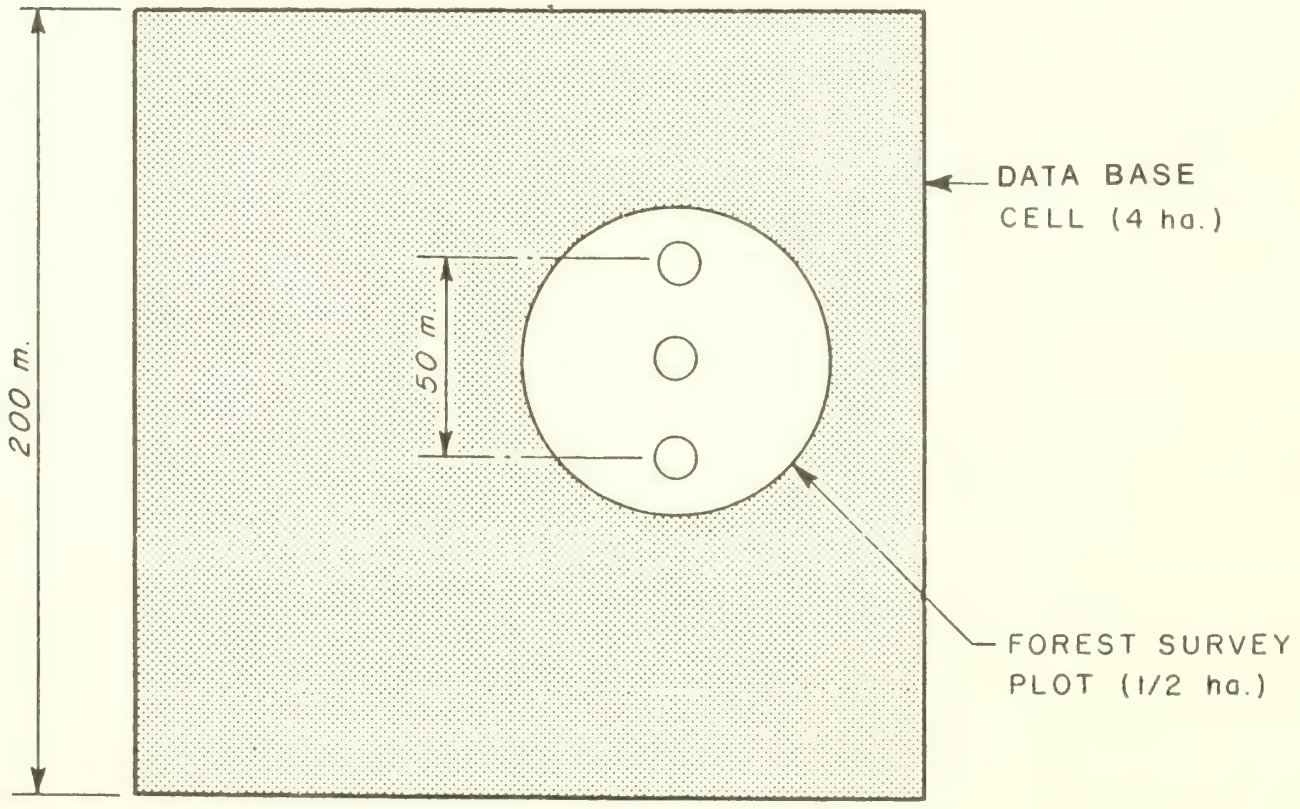

Figure 3.—*Relative sizes of a Landsat data base cell and a forest survey plot area.*

subdivisions of secondary forest and distinct agriculture/forest transition classes were found for each life zone (table 6). The classification scheme and the reflectance values for identical cover types were different for each life zone, indicating that treating each separately improved the overall results.

During processing an evaluation area was selected in each of the life zones, and land cover mapped by photo interpretation. Evaluation areas were selected with good photographic coverage to minimize photo-interpretation errors. The Landsat results were then compared to this "known" cover classification. This preliminary test indicated a fairly accurate forest/nonforest detection capability, with more variable results among specific cover classes (table 7). Detailed cover classes could not be distinguished due to the high proportion of "edge effect" between cover types. Many small farms are used for a variety of purposes, including fruit production, shade, vegetable gardens, etc. These mixed land uses were confused with non-stocked forest land in the moist-forest evaluation area, and agriculture/forest transition in the wet forest evaluation area.

Table 2.—*Area by land use for the haze-free area from 1980 survey data*

Land use	Forest life zone	
	Moist	Wet
	percent	
Forest:		
Nonstocked	5.2	0.0
Secondary	17.4	21.7
Abandoned coffee shade	6.7	17.8
Active coffee shade	1.2	12.6
Total forest	30.5	52.1
Nonforest:		
Inert[1]	12.4	14.8
Cropland[2]	27.8	18.6
Pasture[3]	29.3	14.5
Total nonforest	69.5	47.9
All land	100.0	100.0

[1]Urban and industrial areas, roads, rights-of-way, residential, water, other.
[2]Includes shadeless coffee and idle farmland.
[3]Includes unimproved pasture.

Table 3.—*Photo classification results for 141 field plots*

Land cover	Photo classification		Plots mis-classified	
	Moist forest	Wet forest	Moist forest	Wet forest
	number of plots			
Forest	40	56	18	18
Nonforest	34	11	1	0
Total	74	67	19	18

Table 4.—*Land classification capabilities of black and white aerial photography for secondary forest cover in Puerto Rico*

Cover class	Class description
Inert	Includes urban, residential, and industrial areas; rights-of-way; water; roads; other nonforest and non-agriculture uses.
Cropland	All cropland and orchards, shadeless coffee, and idle farmland.
Pasture[1]	Grassland with less than 10 percent tree and shrub crown closure.
Transition	Grassland with 10 – 50 percent tree and shrub crown closure.
Young secondary	Fine-textured appearance, occasional scattered large crowns, with crown closure more than 50 percent.
Secondary	Uniform intermediate crown texture, with occasional gaps or emergent trees.
Abandoned coffee shade	Coarse texture of large-crowned trees, with occasional gaps or emergent trees.
Active coffee shade	Large-crowned trees form an incomplete upper canopy layer; small trees and other vegetation visible between crowns.

[1] Will include some nonstocked forest land.

Several image processing problems were investigated during the classification procedure. Atmospheric haze partially covered the study area, raising the reflectance values of all land cover types. A test area in the haze region was successfully classified when treated separately. However, since haze conditions were not uniform, numerous classifications would have been necessary to apply this to the entire study area.

Shadowing and variable reflectance in the mountainous terrain also caused problems. Adding digital terrain data to identify additional strata was considered but rejected due to resolution incompatibility. Aspect and elevation change so rapidly in the complex terrain that National Cartographic Information Center digital data resolution excludes microtopographic relief, and an individual data cell would likely show only an average terrain reading.

Merged Cover Estimate

Adjusted Landsat area estimates were nearly identical to adjusted aerial photo dot-count area estimates (tables 1, 8). When ground truth was used to correct Landsat area estimates, similar results were

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Table 5.—*Area by land use for the haze-free area from Landsat data*[1]

Land use	Forest life zone	
	Moist	Wet
	percent	
Forest:		
Nonstocked	8.6	0.0
Young secondary	8.5	25.7
Intermediate secondary	19.0	16.8
Older secondary	10.3	27.6
Total forest	46.4	70.1
Nonforest:		
Inert[2]	21.4	0.2
Agricultural[3]	32.2	29.7
Total nonforest	53.6	29.9
All land	100.0	100.0

[1]Shadowed areas were distributed proportionally among other categories.
[2]Urban and industrial areas, roads, residential areas, water, other.
[3]Pasture, cropland, and agriculture/forest transition (idle farmland and unimporved pasture).

obtained despite a high percentage of misclassified data cells. The sampling error was higher than from photography due to a higher percentage of cell misclassifications, especially in nonforest cover types (table 9). The most common misclassifications occurred in distinguishing small agricultural plots and rural homesteads from forest land, much of which is in transition from the nonforest to forest category.

DISCUSSION

During project execution, some problems surfaced regarding merged forest survey and Landsat data. For example, the field plots were too small, and photo interpretation too unreliable to extend the point sample cover class to a larger area which could be used for training. Also, the field plots were widely dispersed over the study area, and usable plots near identifiable features did not represent the full range of cover diversity. Several additional training sites were visited to complete the Landsat classification.

Certain processing techniques showed promise and will be tested in future projects. Preliminary data stratification, including haze level and detailed terrain classification, would effectively partition the data into relatively uniform subsets within each life zone. Each strata would then be classified separately using internal training statistics. Disadvantages to this approach are the additional time needed to perform the classification and extra ground truth requirements.

Some problems could be avoided if a better selection of aerial photographs or Landsat data were available. Persistent cloud cover, common in mountainous tropical areas, makes complete, cloud-free photographic coverage difficult to obtain. This also reduces the likelihood of the Landsat satellite passing overhead on a clear day. Puerto Rico's location outside a Landsat data receiving station compounds the problem; only a single year of data was available.

In sum, the study has identified some opportunities and problems associated with using remote sensing for forest area estimation in Puerto Rico. Both Landsat data and aerial photography gave roughly

Table 6.—*Cover classes discriminated from Landsat data*

Forest life zone	Cover class	Class description
Moist	Inert	Includes all highly reflective areas; construction, urban, residential, bare soil, clouds.
Moist, wet	Agriculture (crop and pasture)	Land primarily used for cropland or pasture with less than 10% brush cover or stocking; scattered trees are common.
Wet	Agriculture/ forest transition	Low density brush/pasture, and forest/pasture edge.
Moist	Non-stocked forest (early transition)	Degraded and fallow cropland or pasture; small brush and ferns may predominate with scattered large trees common.
Moist, wet	Young secondary forest	Pasture or cropland with moderate to dense brush cover, reverting to forest, although occasional grazing may occur. Young growth is generally less than 5 m tall with or without larger old field trees scattered throughout or in clumps.
Moist, wet	Intermediate secondary forest	An intermediate stand structure where younger trees have reached the height of older trees; generally a relatively smooth canopy texture.
Moist, wet	Older secondary forest	Scattered larger dominant stems cause coarser canopy texture; considerable variation in individual crown tones.
Moist, wet	Shadow	Heavily shadowed areas, generally terrain shadowing; shadow/forest transition pixels; cloud shadows; and shadow/water transition.
Moist, wet	Water	All turbidity classes were grouped.

comparable area estimates. Each data source has unique classification problems originating with the difficult terrain and intermixed land uses found in many mountainous tropical regions. The study has demonstrated that Landsat MSS data is a viable alternative to panchromatic photographic data for area estimation in forest surveys. Where cloud- and haze-free Landsat data is available, photographic missions under difficult atmospheric conditions are unnecessary. Unfortunately, clear conditions are rare for many tropical mountain regions, and Landsat data availability is often sporadic. Complete digital cover classification under clouds or severe haze would require additional imagery, such as radar, which is not significantly affected by atmospheric conditions.

Table 7.—*Comparison of photo interpreted land cover and Landsat solution for two evaluation areas*

Forest life zone	Cover class	Photo results	Landsat results
		—*percent*—	
Moist	Forest:		
	Nonstocked	3	14
	Young secondary	1	9
	Intermediate secondary	78	55
	Older secondary	7	17
	Total forest	89	95
	Nonforest:		
	Agriculture and inert	11	5
		100	100
Wet	Forest:		
	Nonstocked	3	0
	Young secondary	6	18
	Intermediate secondary	80	18
	Older secondary	4	43
	Total forest	93	79
	Nonforest:		
	Agriculture and inert	7	1
	Agriculture/Forest transition	0	20
	Total nonforest	7	21
		100	100

Table 8.—*Forest cover estimates for the haze-free study area from merged forest survey and Landsat data*

Forest life zone	Total area	Proportion of forest land		Sampling error[1]
		Unadjusted	Adjusted	
	hectares	——	*percent*	——
Moist	122,484	46.4	30.0	5.3
Wet	82,888	70.1	57.0	6.0
Total	205,372	55.9	40.9	

[1]By random-sampling formula, 67 percent probability level.

Table 9.—*Landsat classification results for 141 field plots*

Land cover	Photo classification		Plots mis-classified	
	Moist forest	Wet forest	Moist forest	Wet forest
	——	*number of plots*	——	
Forest	39	46	25	19
Nonforest	35	21	9	11
Total	74	67	34	30

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Additional Keywords: Tropical forest inventory, remote sensing, forest resources.

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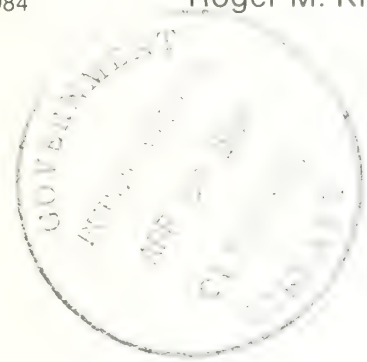
Cottonwood Plantation Growth Through 20 Years

Roger M. Krinard and Robert L. Johnson



SUMMARY

At age 20 survival of unthinned cottonwood (*Populus deltoides* Bartr. ex Marsh.) planted on medium-textured soil at spacings of 4 by 9, 8 by 9, 12 by 12, and 16 by 18 feet was 10, 17, 30, and 62 percent, and average diameters were 10.6, 11.8, 12.6, and 13.7 inches, respectively. Depending on spacing and diameter threshold, cubic volume mean annual increment peaked at ages 7 to 13. Thinning compared to no thinning reduced cubic volume production. Thinned or unthinned plots of 16- by 18-foot spacing and heaviest thinning at 12 by 12 spacing produced from 340 to 400 board feet per acre per year (Doyle) during the 20 years in trees ≥ 12.0 inches to a 10-inch top. Other spacing-treatment combinations provided from 110 to 230 board feet per acre per year.

Cottonwood Plantation Growth Through 20 Years

Roger M. Krinard and Robert L. Johnson

INTRODUCTION

Cottonwood is a valuable source of veneer, lumber and pulp and the fastest growing tree species in the South. From 1961 through the mid-1970's, an estimated 40,000 to 50,000 acres of eastern cottonwood (*Populus deltoides* Bartr. ex Marsh.) were planted in the lower Mississippi River Valley (Burkhardt and Krinard 1976); however, the subsequent rate of planting has declined. Generally, initial tree spacings were 9 by 9 or 10 by 10 feet to accommodate traditional farm equipment for first-year mechanical cultivation. At those spacings, trees were expected to reach pulpwood size by the first thinning, require no pruning, and provide adequate stocking if two-thirds of the trees survived.

A study to compare the relationship of diameter and volume growth to initial spacing and basal area control of stocking in cottonwood plantations during the first 10 years (Krinard and Johnson 1975) and the following 5 years (Krinard and Johnson 1980) has been reported. This final paper on the study provides a summary of previous work and additional information through age 20.

METHODS

The study was located on Crown Zellerbach land outside the main Mississippi River levee near Fitler, Mississippi, on medium textured soils, mainly Commerce and Convent silt loams (thermic family of Aeric Fluvaquents). Estimated site indices of these soils, for natural cottonwood stands, range from 105 to 125 feet at age 30 (Broadfoot 1976).

Standard 20-inch unselected cuttings obtained from the Winona State Nursery and the company nursery at Fitler were planted in January 1963 at spacings of 4 by 9, 8 by 9, 12 by 12, and 16 by 18 feet. Plots were about 250 feet square, with a 144-foot square measurement plot centered within each plot. A randomized complete block design with four replications of four spacings and four future thinning treatments were planted; however, losses, primarily to deer, reduced the planting to eight plots per spacing. After the fourth year, plots were arrayed according to basal area within spacings, and thinning treatments were randomly assigned to the four plots with the highest and lowest basal areas.

The study area had been in pasture for many years and was pan-plowed 14 inches deep before planting. Plots were disked during the first year for weed control. After the first year the plots were only mowed in late summer through age 10.

Four thinning treatments were planned to reduce basal area per acre to 40, 65, 90, and 115 square feet whenever these levels were exceeded by 15 square feet. The two plots per spacing to be thinned to 115 square feet never reached that level, were never thinned, and thus served as checks. The two plots each of the 4 by 9 and 8 by 9 spacings were reduced from 105 square feet to 50 square feet, rather than 90 square feet, because experience had shown lack of response to thinning 15+ square feet from basal area levels of 55+ and 80+ square feet.

After 15 years, plots other than the check plots were reduced to 46 trees per acre if they were not already at least to that stocking level. The reasoning was that after 15 years pulpwood was not the major consideration, and the creation of sawlog growing conditions was needed.

Thinning was from below with spacing being the major consideration after removing the obviously weak, poorly formed trees.

For spacings of 4 by 9 and 8 by 9, 55+ to 40 basal area thinnings were initiated at age 4 (average dbh 3.2 and 4.4 inches). The 80+ to 65 basal area thinnings began at age 5 (average

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dbh 3.8 and 5.2 inches). Thinnings were done at 2- to 3-year intervals. The 105+ to 50 basal area thinning was done after the 9th year (average dbh 5.4 and 6.0 inches).

For 12 by 12 spacing, 55+ to 40 thinnings began at age 5 (average dbh 7.0 inches), and the 80+ to 65 thinnings began at age 8 (average dbh 7.9 inches), with from 2 to 4 years between thinnings. The 55+ to 40 thinnings at 16-by 18-foot spacing came at year 7 or 8 (average dbh 9.6 inches) and again at year 10 or 11.

From age 1 through 3, plots were sampled for survival. From age 4 through 20, diameters of all trees taller than 4.5 feet were measured with calipers. Dominant tree heights were randomly sampled after the 4th, 6th, 8th, 10th, 15th, and 20th years.

Sample tree volumes were obtained from cut trees and from standing trees using a Barr and Stroud dendrometer. The tree volumes were then used in constructing local volume tables, with 1-inch dbh classes, for plot volume estimates. Merchantable cubic-foot volume was calculated for volume outside bark in trees ≥5.0 inches dbh to a 4-inch top outside bark. Total volume was stem volume outside bark to a total height for trees ≥2.0 inches dbh. Board-foot volumes were obtained for trees ≥12.0 inches dbh to a 10-inch upper diameter inside bark.

The study had two replications. Statistical comparisons were made among the unthinned plots of the four spacings as they suffered no unusual losses through the 20 years. As some thinned plots were lost to storm damage, no other statistical analyses were made.

RESULTS AND CONCLUSIONS

Figures 1 through 9 show trends over time for check plots by spacings for survival, dbh, basal area, and cubic- and board-foot volumes. Tables 1 through 4 provide 20-year average diameters and total basal areas and volumes by spacings for residuals, mortality, and thinnings.

Generally, the results show closer spacings lead to longer planting times and more cuttings, earlier and greater mortality, smaller average diameters, greater basal area mean annual increment (mai), earlier and greater total volume mai, and less board-foot production.

Specifically, the 4 by 9 spacing yielded many small trees which did not reach merchantability, whether through thinnings or mortality. This spacing may be termed more aptly a fiber or biomass spacing rather than a pulpwood spacing. Utilization of the majority of the trees from the spacing would probably mean using both bark and wood because of small tree sizes involved. Maximum total volume mai was produced, but by only 2 percent more than 8 by 9 spacing on 86 percent more trees. Average diameters of 6 and 8 inches were reached in 12 and 16 years with survival of 40 and 18 percent. With the inherent drawbacks in large tree numbers and small sizes, plus first-year weed control problems because of close spacing (too close for cross disking), the 4 by 9 spacing has little to offer the cottonwood grower.

The 8 by 9 spacing is a pulpwood spacing. Two-thirds and three-fourths of the trees were 5.0 inches dbh or larger at peak mai for total (7th year) and merchantable (9th year) volumes. While maximum merchantable volume mai was produced, it was only 6 percent more than 12 by 12 spacing on 52 percent more trees ≥5.0 inches dbh, plus nearly 80 more trees per acre less than 5.0 inches. Fewer than 50 percent of the cut trees in the heaviest thinning—to favor better trees for potential sawtimber development—had reached 5.0 inches dbh. Doyle board-foot volume mai through 20 years was less than 235 board feet per acre per year. Average dbh's of 6, 8, and 10 inches were reached at 8, 13, and 16 years when survival was 70, 44, and 27 percent, respectively.

The 12 by 12 spacing may be the best compromise of the spacings tried, and considered as either a pulpwood spacing or a pulpwood and sawtimber combination. The maximum merchantable volume mai was only 0.2-cord per acre per year less than the 8 by 9 spacing. The heaviest thinning, where nearly 90 percent of the cut trees were of merchantable size, provided 350 Doyle board feet per acre per year over 20 years. Average diameters of 6, 8, 10, and 12 inches were reached in 5, 9, 14, and 18 years with survival of 79, 75, 60, and 34 percent, respectively.

The 16 by 18 spacing provides a pulpwood-sawtimber combination, producing lowest maximum cubic volume mai's but maximum Doyle board-foot mai (fig. 10). The merchantable volume peak mai was 8 percent less than 12 by 12 spacing and 14 percent less than 8 by 9 spacing in 56 and 137 percent fewer trees. Thinned or unthinned plots produced from 340 to 400 board feet per acre per year—residual plus cut—during the 20 years. Average diameters of 6, 8, 10, and 12 inches were reached in 5, 7, 10, and 15 years, respectively, with survival of 90, 90, 88, and 76 percent.

Spacing influence on diameter and volume growth over time may be analyzed by using the 38 largest trees per acre (to be comparable to

Figure 1.—*Survival of check plots.*

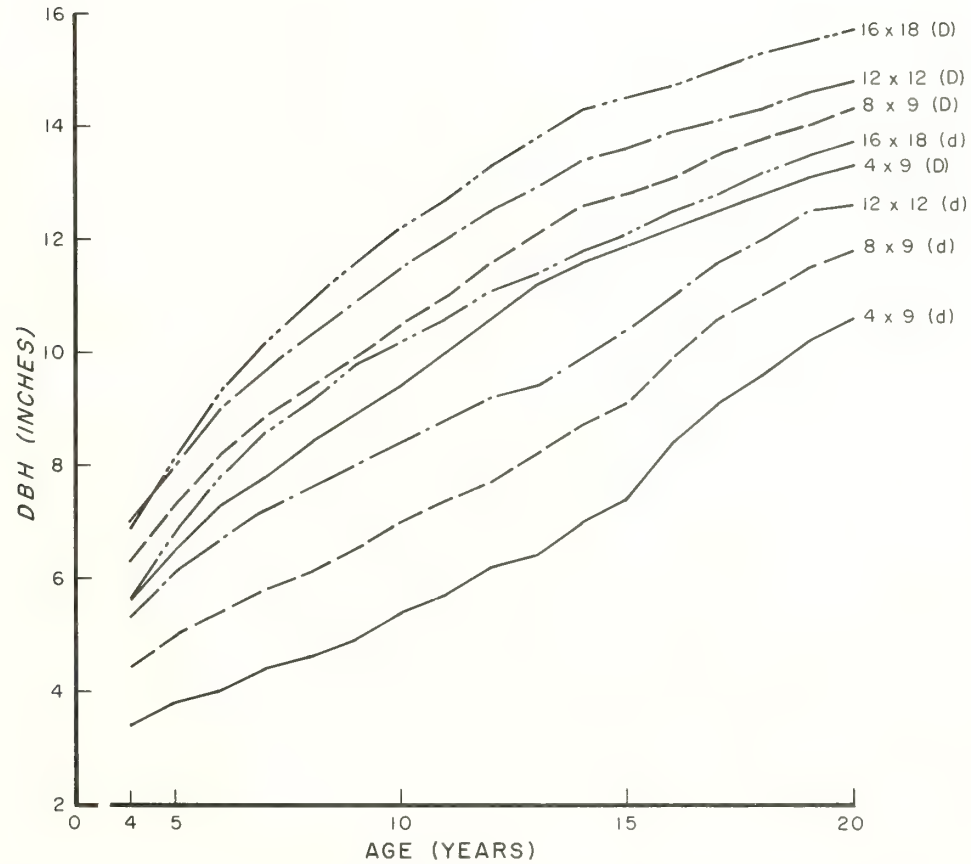

Figure 2.—*Average dbh of all trees (d) and average dbh of largest 38 trees per acre at age 20 (D) in check plots.*

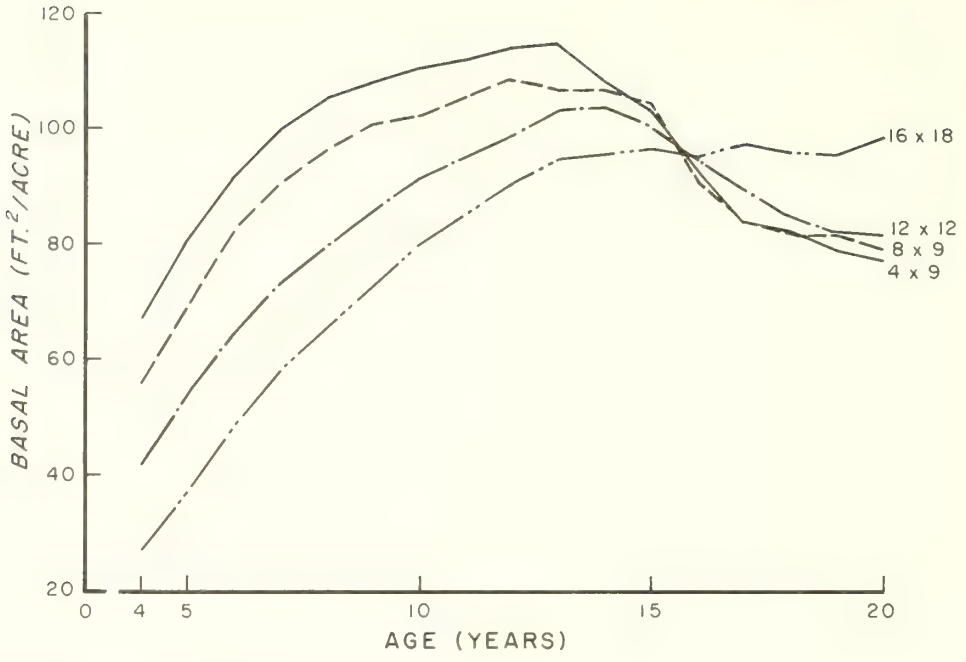

Figure 3.—*Basal area of check plots.*

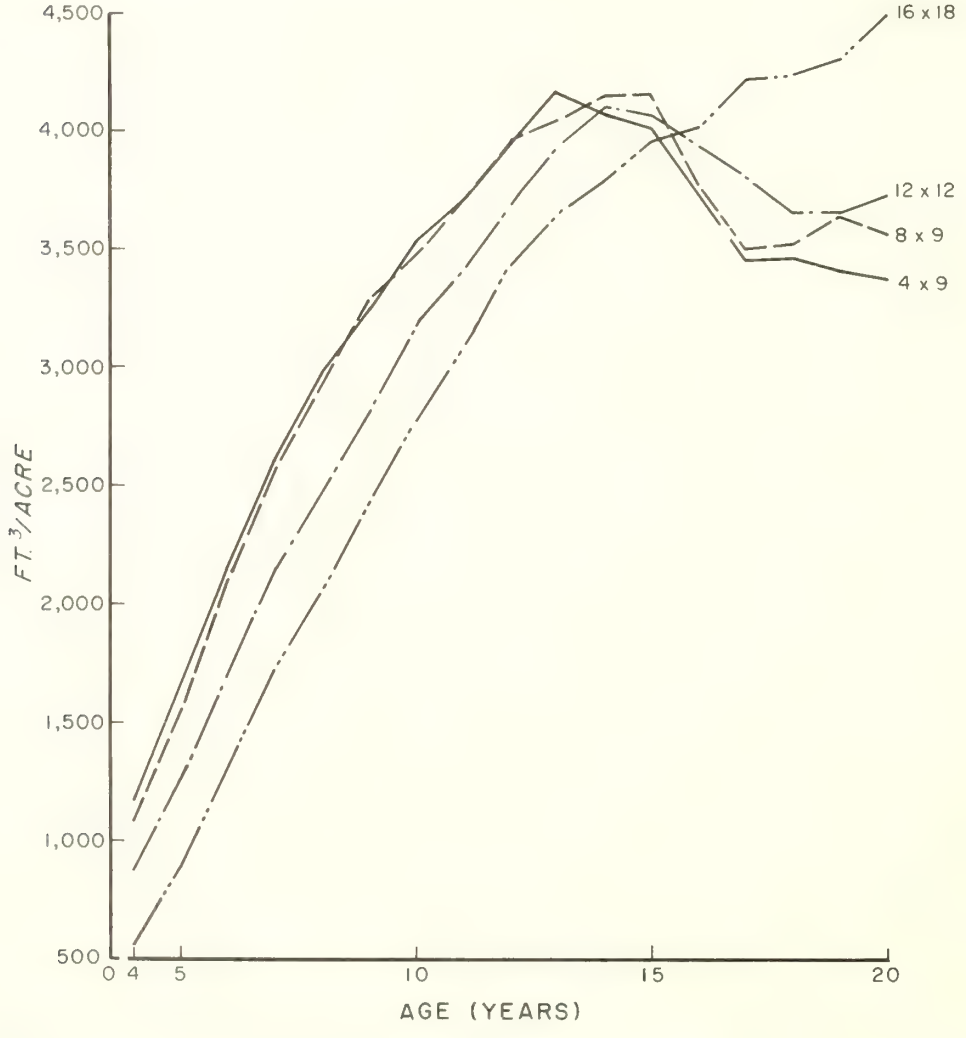

Figure 4.—*Total cubic volume for check plots.*

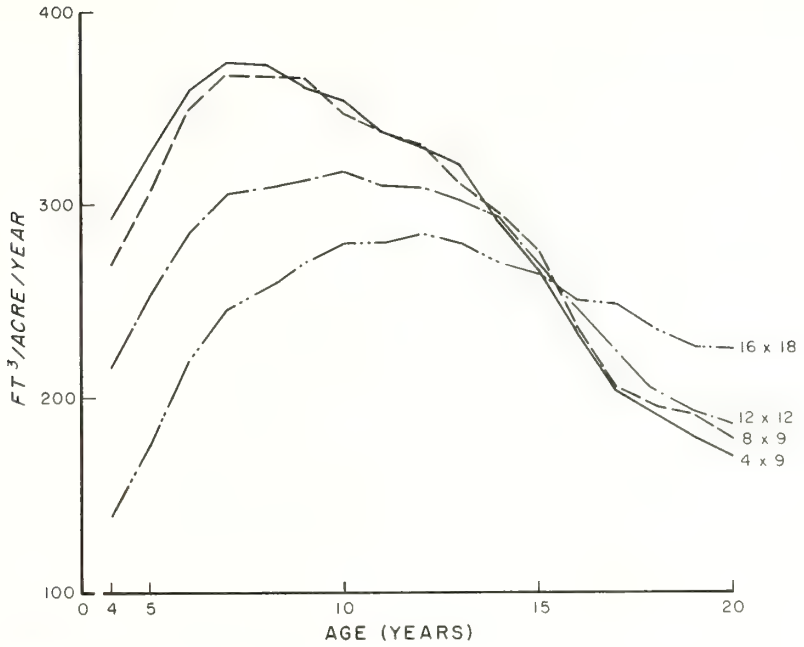

Figure 5.—*Mean annual increment of total cubic volume of check plots.*

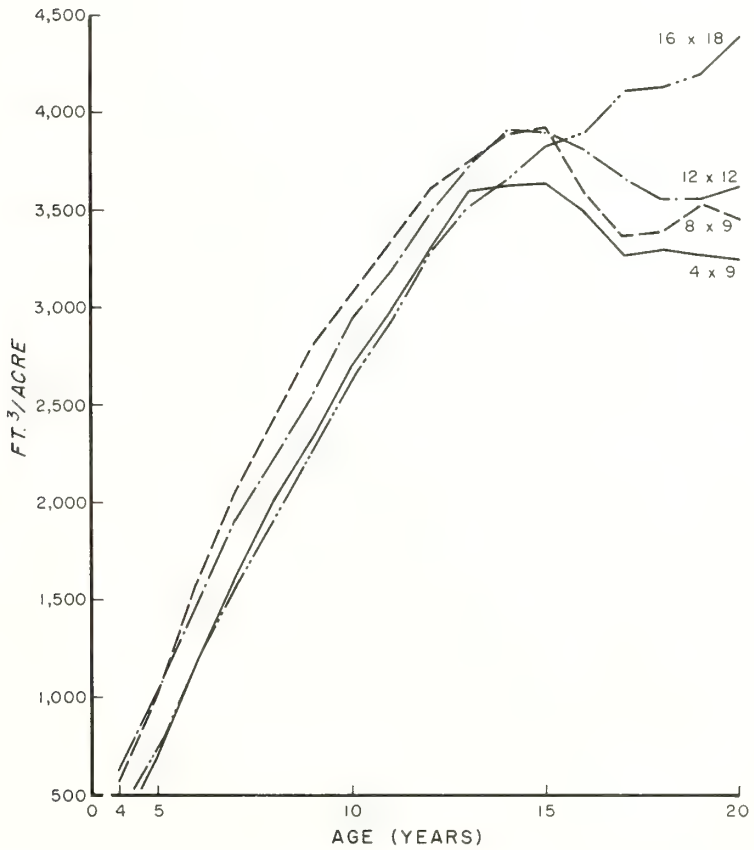

Figure 6.—*Merchantable cubic volume for check plots.*

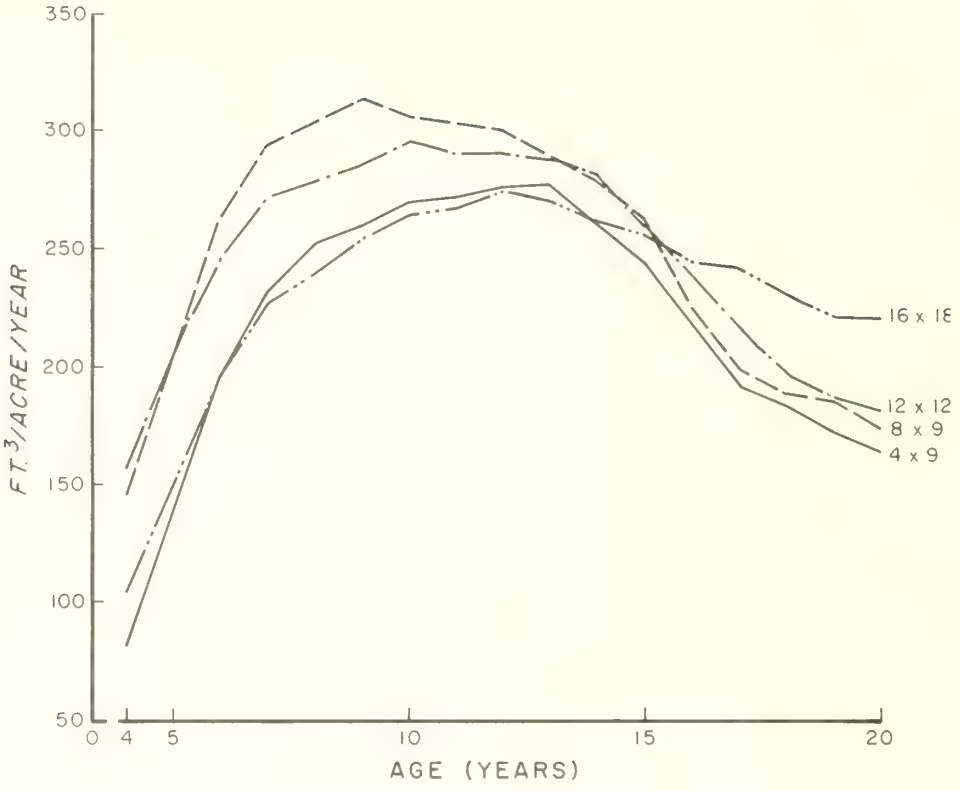

Figure 7.—*Mean annual increment of merchantable cubic volume of check plots.*

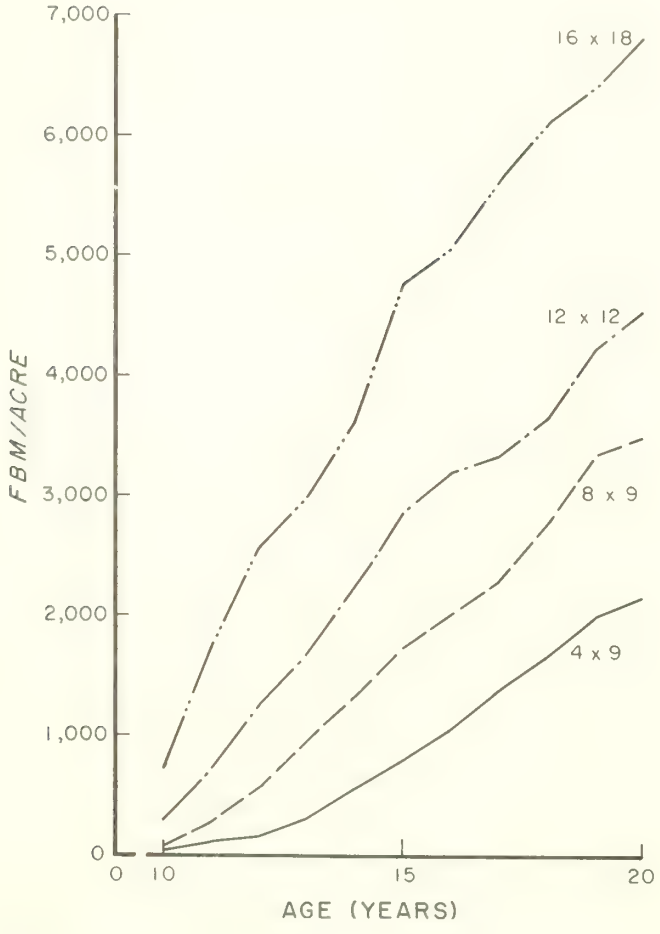

Figure 8.—*Doyle board foot volume for check plots.*

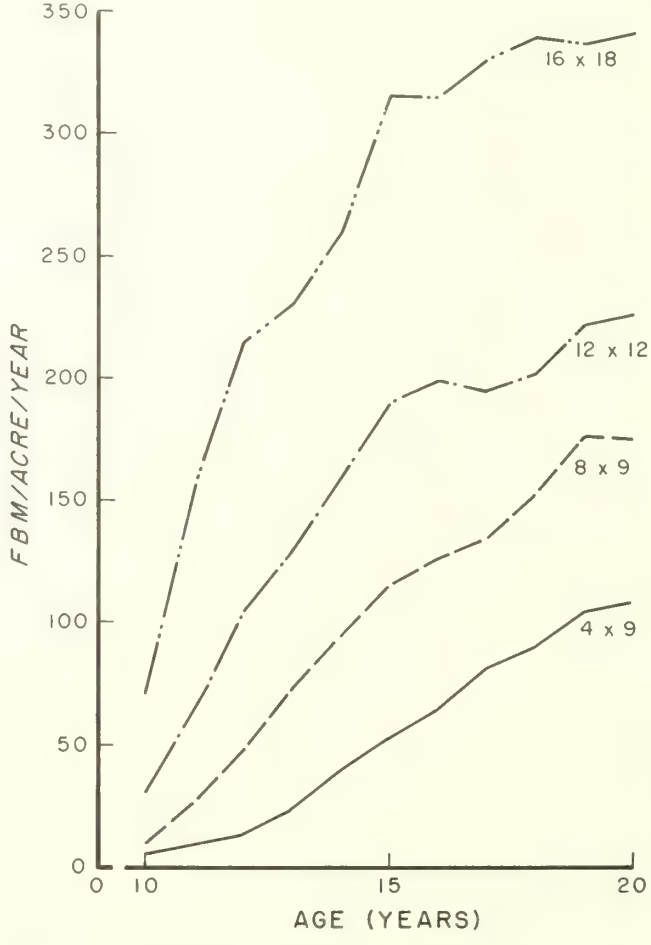

Figure 9.—*Mean annual increment of Doyle board foot volume for check plots.*

Table 1.—*Average dbh by spacings and thinning treatments at age 20*

Spacing	Thinning treatments				
	55+ to 40 ft²/A	80+ to 65 ft²/A	105+ to 50 ft²/A	15[1]	Check
feet	*inches*				
4×9	14.8	13.5	13.9	...	10.6
8×9	14.6	14.6	14.1	...	11.8
12×12	16.5	14.6	...	14.3	12.6
16×18	17.4	...	...	15.2	13.7

[1]Thinned only at age 15 to 46 trees per acre.

Table 2.—*Basal area per acre by spacings and thinning treatments for (1) age 20, (2) thinnings from age 4 through age 15, and (3) mortality from ages 5 through 20*

Spacing	Thinning treatments				
	55+ to 40 ft²/A	80+ to 65 ft²/A	105+ to 50 ft²/A	15	Check
feet	*ft² acre*				
4×9					
Age 20	46.2	41.3	45.2	...	76.9
Cut	99.3	103.0	95.2	...	...
Mortality	10.4	14.8	21.0	...	86.6
	155.9	159.1	161.4		163.5
8×9					
Age 20	46.7	51.4	50.9		79.2
Cut	78.4	96.4	90.4	...	...
Mortality	13.1	7.0	9.7	...	73.0
	138.2	154.8	151.0		152.2
12×12					
Age 20	57.5	50.4	...	44.7	81.6
Cut	58.3	63.6	...	51.2	...
Mortality	13.4	9.5	...	20.3	46.3
	129.2	123.5		116.2	127.9
16×18					
Age 20	61.2	...	...	57.6	98.2
Cut	38.6	...	...	49.4	...
Mortality	6.4	...	...	4.6	20.4
	106.2			111.6	118.6

[1]Thinned only at age 15 to 46 trees per acre.

Table 3.—*Number of trees and volumes by dbh classes and unthinned spacings for age 20 and mortality from ages 5 through 20*

Spacing (*feet*)	Dbh classes (*inches*)									
	<2	2–4		5–11		12+		Total		
	N/A[1]	N/A	ft³/A[2]	N/A	ft³/A	N/A	ft³/A	N/A	ft³/A	fbm/A[3]
4×9										
Age 20	...	3.1	8	84.0	1884	32.6	1486	119.7	3378	2168
Mortality	115.6	437.0	676	234.2	2075	...	...	786.8	2751	...
	115.6	440.1	684	318.2	3959	32.6	1486	906.5	6129	2168
8×9										
Age 20	...	2.1	6	55.6	1363	44.1	2193	101.8	3562	3493
Mortality	24.2	130.3	226	210.1	2324	1.0	43	365.6	2593	63
	24.2	132.4	232	265.7	3687	45.1	2236	467.4	6155	3556
12×12										
Age 20	...	1.0	3	34.7	951	54.6	2765	90.3	3719	4521
Mortality	16.8	25.2	41	108.2	1598	4.2	152	154.4	1791	168
	16.8	26.2	44	142.9	2549	58.8	2917	244.7	5510	4689
16×18										
Age 20	...	...	...	21.0	576	72.4	3916	93.4	4492	6832
Mortality	3.2	4.2	9	27.3	482	8.4	321	43.1	812	430
	3.2	4.2	9	48.3	1058	80.8	4237	136.5	5304	7262

[1]Trees per acre.
[2]Cubic-foot volume per acre.
[3]Doyle board-foot volume per acre.

Table 4.—*Number of trees and volumes by dbh classes and spacings-by-thinning treatments for (1) age 20, (2) thinnings from ages 4 through 15, and (3) mortality from ages 5 through 20*

Spacing (*ft*) and thinning (ft^2/A)	Dbh classes (*inches*)									
	2	2-4		5-11		12+		Total		
	N/A[1]	N/A	ft^3/A[2]	N/A	ft^3/A	N/A	ft^3/A	N/A	ft^3/A	fbm/A[3]
4×9: 55+/40										
Age 20	...	...	...	3.1	99	35.7	2045	38.8	2144	3948
Cut	161.8	647.0	687	198.5	1914	1.0	36	1008.3	2637	38
Mortality	...	...	...	13.6	215	4.2	169	17.8	384	242
	161.8	647.0	687	215.2	2228	40.9	2250	1064.9	5165	4228
4×9: 80+/65										
Age 20	...	...	...	3.1	93	37.8	1765	40.9	1858	2566
Cut	129.2	508.4	637	230.0	2578	2.1	72	869.7	3287	76
Mortality	52.5	11.6	23	29.4	345	4.2	150	97.7	518	164
	181.7	520.0	660	262.5	3016	44.1	1987	1008.3	5663	2806
4×9: 105+/50										
Age 20	...	...	...	5.2	165	36.8	1906	42.0	2071	3164
Cut	13.6	255.2	430	253.2	2664	4.2	150	526.2	3244	176
Mortality	79.8	166.0	178	33.6	348	1.0	44	280.4	570	63
	93.4	421.2	608	292.0	3177	42.0	2100	848.6	5885	3403
8×9: 55+/40										
Age 20	...	...	...	3.1	88	36.8	2076	39.9	2164	3803
Cut	28.4	244.8	318	209.0	1812	1.0	33	483.2	2163	30
Mortality	...	...	...	10.5	245	7.4	264	17.9	509	313
	28.4	244.8	318	222.6	2145	45.2	2373	541.0	4836	4146
8×9: 80+/65										
Age 20	...	...	...	1.0	33	43.1	2360	44.1	2393	4178
Cut	23.1	167.0	239	238.4	2703	8.4	315	436.9	3257	405
Mortality	10.5	3.1	3	14.7	170	2.1	78	30.4	251	95
	33.6	170.1	242	254.1	2906	53.6	2753	511.4	5901	4678
8×9: 105+/50										
Age 20	...	...	...	2.1	55	44.1	2305	46.2	2360	3915
Cut	7.3	139.8	264	251.0	2673	5.2	179	403.3	3116	189
Mortality	9.4	35.7	43	17.8	217	1.0	35	63.9	295	30
	16.7	175.5	307	270.9	2945	50.3	2519	513.4	5771	4134
12×12: 55+/40										
Age 20	...	...	...	1.0	27	35.7	2654	36.7	2681	6768
Cut	3.1	20.0	29	151.3	1470	6.3	228	180.7	1727	338
Mortality	...	...	...	6.3	144	9.4	381	15.7	525	561
	3.1	20.0	29	158.6	1641	51.4	3263	233.1	4933	7667
12×12: 80+/65										
Age 20	...	...	...	3.1	99	39.9	2201	43.0	2300	4022
Cut	3.1	28.4	54	129.2	1909	8.4	356	169.1	2319	594
Mortality	3.1	5.2	7	12.6	265	2.1	83	23.0	355	120
	6.2	33.6	61	144.9	2273	50.4	2640	235.1	4974	4736
12×12:[4]										
Age 20	...	...	...	2.1	66	37.8	2017	39.9	2083	3341
Cut	2.1	2.1	1	105.0	2031	...	...	109.2	2032	...
Mortality	10.5	23.1	29	56.7	525	4.2	156	94.5	710	191
	12.6	25.2	30	163.8	2622	42.0	2173	243.6	4825	3532
16×18: 55+/40										
Age 20	...	...	...	...	...	36.8	2924	36.8	2924	7532
Cut	3.1	3.1	6	55.6	846	12.6	409	74.4	1261	458
Mortality	...	1.0	2	2.1	33	4.2	221	7.3	256	473
	3.1	4.1	8	57.7	879	53.6	3554	118.5	4441	8463
16×18:[4]										
Age 20	...	...	...	1.0	33	44.1	2611	45.1	2644	5114
Cut	...	1.0	3	41.0	853	27.3	1165	69.3	2021	1900
Mortality	4.2	4.2	9	9.4	116	1.0	37	18.8	162	38
	4.2	5.2	12	51.4	1002	72.4	3813	133.2	4827	7052

[1]Trees per acre. [2]Cubic-foot volume per acre. [3]Doyle board-foot volume per acre.
[4]Thinned only at age 15 to 46 trees per acre.

thinned plots) in each unthinned plot after 20 years and comparing growth by 5-year periods. The dbh growth differential between spacings was greatest in the first 5-year period, but the 12 by 12 and 16 by 18 spacings did not differ and were significantly greater (0.05 level) than all other spacing-period combinations. During the second 5-year period, growth of trees at the widest spacing was greater than at the other spacings. Spacings did not influence dbh growth in either the third or fourth 5-year periods. Within spacings, each succeeding 5-year growth period was less than the previous period except the second and third period did not differ at 4 by 9 spacing. From 49 to 55 percent of the 20th-year dbh, depending on spacing, was obtained by year 5.

For the three closer spacings, the upper basal area limits ranged from about 105 to 115 square feet per acre while peak cubic volumes per acre, which occurred from ages 13 to 15, were slightly better than 4000 cubic feet. Basal area—nearly 100 square feet per acre—and total cubic volume—about 4500 cubic feet per acre—were maximum at age 20 for 16 by 18 spacing.

Thinning, as done in this study, tended to reduce mortality if initiated by age 7 and generally gave largest average diameter at age 20 with heaviest thinning. Compared to not thinning, total basal area production—residual, cut, and mortality—was similar or less while cubic volume production was reduced.

Total heights of dominant/codominant trees at age 20 averaged 106 feet for both unthinned and thinned plots. Average height growth over the last 5 years was only 6 feet. Prior growth of tallest trees approximated 12 feet annually the first 4 years, 8 feet annually during the next 4 years, and 3 feet annually for the next 7 years.

This was the first large-scale spacing-thinning study with cottonwood in the Midsouth with a management objective to produce veneer and sawlog size trees along with intermediate products as they occurred on a maximum growth rate basis. A rotation of 30 years was planned. However, at the start of the 21st growing season a windstorm destroyed 120 trees, including some of the largest, and the study was closed. This was the fourth weather-related tree loss, starting with flooding from the Mississippi River in the 11th year and accompanying windthrow and broken stems. Flooding increased incidence of stem canker and possibility of future stem breakage. Although this study may or may not be representative of average storm-related damages, all cottonwood plantings in the batture have the potential for flooding and accompanying problems. Thus, long-term, i.e., sawtimber, plantations on these sites have a built-in risk factor which may decrease yields.

Figure 10.—*Unthinned, 20-year-old cottonwood planted at 16- by 18-foot spacing with 58 percent survival, 13.6 inches average diameter, and 6,600 board feet per acre, Doyle, to a 10-inch top dib.*

Very rapid early diameter and height growth characterize cottonwood plantings, with diameter growth peaking in the third or fourth year regardless of spacing. Cottonwood, if it is to continue rapid growth, cannot tolerate side competition, so wide spacings or early thinnings at close spacings prior to severe competition are needed. Thinnings in this test, which removed too few trees or occurred too late, may have helped maintain growth of residual trees but did not increase growth. There was no observable response of crown growth into created openings. An estimated 40 percent or more live crown ratio is needed for good growth, as measured on dominant and codominant cottonwood in natural stands (Johnson and Burkardt 1976).

The last 5 years of plantation development added nothing to previous conclusions regarding spacings for pulpwood production and for both

pulpwood and sawtimber production. To reiterate, 8 by 9 and 12 by 12 spacings are recommended for pulpwood production. Volume mai peaked from the 7th to 10th years, depending on spacing and merchantability limits. For pulpwood production, no thinnings are needed. The 12 by 12 and 16 by 18 spacings appear feasible for producing both pulpwood and sawtimber. A possible method of treating the spacings would involve one or two pulpwood thinnings, taking half the trees at each thinning at about 60 square feet of basal area, to put both spacings at a 24 by 24 spacing. At least one sawtimber thinning, when basal area reaches 80 to 100 square feet per acre, should provide a final crop of about 38 trees with average dbh of 24 inches and 120 square feet of basal area. Rotation age to 24 inches is not precisely known.

In the publication based on the 15-year results of this study (Krinard and Johnson 1980), it was estimated that thinned plots of the two widest spacings might produce 23,000 board feet in 30 years, which would be similar to yields on unthinned natural stands found by Johnson and Burkhardt (1976). The yield prediction assumed an average dbh of 24 inches, merchantable length of 3½ logs, and 40 trees per acre. The 24-inch dbh figure assumed 15- and 16-inch trees would grow 8 to 9 inches in 15 years, or 2.7 to 3.0 inches in 5 years. Unless the ever-decreasing diameter growth rates were reversed—the same trees surviving after 20 years in the thinned plots of the two wider spacings grew 7.9, 3.8, 2.6, and 1.4 inches by 5-year growth intervals—there would be no way for the trees to average 24 inches in 30 years. Even the two plots of the 16 by 18 spacing, which received the heaviest thinning and have been stocked with 42 trees per acre or less since the 12th growing season, only grew 1.5 inches in the past 5 years. The trees have room to grow but do not have the crown development of dominant/codominant trees of natural stands.

An obvious conclusion is that wider initial spacings, with pruning for quality, should be used where a sawtimber rotation of less than 30 years is the objective. Even wider spacing, though taking advantage of very rapid early diameter growth, may not maintain that growth for much longer intervals. For example, diameter growth of unpruned trees at 40 by 40 spacing (27 trees per acre) grew 5.0 inches from age 6 through 10 (unpublished data on file at the Southern Hardwoods Laboratory, Stoneville, Mississippi), but the 27 largest trees per acre in the unthinned 16 by 18 spacing grew 4.2 inches in the same period—less than an inch difference in 5 years. The big difference, though, occurred in the first 5 years when diameter growth of the two spacings was 11.4 (Krinard 1979) and 8.0 inches.

For sawtimber production, is there a spacing which would produce 24-inch trees with two high quality logs in 20 years? Maybe, but unpruned trees in the previously mentioned 40 by 40 spacing which were 16.4 inches in 10 years, were growing 0.8 inch a year in the 8th through 10th years. If that growth could be maintained for 10 years, 24-inch trees would be possible, but limbs would make trees low in stumpage value. As pruning reduces diameter growth, 24-inch trees in 20 years does not appear to be reasonable expectation over large areas. Assumptions, based on extrapolation of growth of existing plantations and known pruning effects on diameter growth, indicate 28 by 28 to 32 by 32 spacing may produce 20-inch trees and 11,000 to 12,000 board feet in 20 years and nearly 25-inch trees and 21,000 to 22,000 board feet in 30 years.

Direct comparisons with European methods are difficult. Although their culture is much more intensive, an average guide for good sites in the Po River Valley in Italy showed 12.5-inch trees in 15 years with 202 trees per acre (about 15-foot spacing) and 18.2-inch trees in 20 years with 96 trees per acre (about 21-foot spacing) (Food and Agriculture Organization of the United Nations 1979).

Wider spacings provide less than full site utilization, require intensive pruning, and the trees are still subject to flooding, wind damage, cankers, and insects. Because of the costs and risks involved, cottonwood from planting may not be suitable for long rotations for some landowners. Either a change in utilization standards, so that smaller trees and shorter rotations are feasible, or higher stumpage values which would justify higher management costs, or different management practices and/or clones, which would sustain early plantation growth, could change that outlook.

The main factors favoring cottonwood plantings are the very rapid early growth and early returns. Negative factors are high plantation establishment costs and, for sawtimber and veneer logs, long-term weather risks, and lack of data on alternative cultural methods and superior clone performance in long rotation management.

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Twenty-year summary of a cottonwood study that compares the relationship of diameter and volume growth to initial spacing and basal area control of stocking.

Additional keywords: *Populus deltoides*, stand development, thinning.

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Department of
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Ecological Assessment of the Roaring Branch Research Natural Area

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INTRODUCTION

The Roaring Branch Research Natural Area (RBRNA) was established in 1968 as a part of a nationwide effort to preserve examples of unique vegetative types. The area contains old-growth hardwood and shortleaf pine, probably components of the virgin stand. Showing no evidence of commercial harvest or recent fires, present vegetation probably represents a natural ecological succession relatively undisturbed by man (Ferguson 1968).

The RBRNA is located on the Caddo Ranger District of the Ouachita National Forest, about 51 km (32 miles) west of Glenwood, Arkansas. The area comprises the upper part of the Roaring Branch watershed and includes about 121 ha (300 acres) in Sections 26, 27, and 28, Township 4 South, Range 28 West, Fifth Principal Meridian, Polk County, Arkansas.

The area is accessible only by foot-trail from Forest Service Road 106 (Blaylock Rd.). Details concerning access and use can be obtained from the USFS Southern Forest Experiment Station.

PHYSIOGRAPHY—SOILS AND CLIMATE

The RBRNA lies in the Central Ouachita Mountains subdivision of the Ouachita Mountain physiographic province. These mountains are characterized by east-west parallel ridges, which are typical of much of the province. Rocks of this subdivision are a combination of igneous rock and sedimentary rock of novaculite, sandstone and shale. They represent several geologic ages. Ridges have sharp, rather narrow crests and tend to be very rugged with numerous large rock outcrops (Arkansas Dept. of Planning 1974).

The east-west orientation creates either north or south facing slopes with widely differing local climatic conditions. The overall climate of the RBRNA is one of hot summers and moderately cold winters. Precipitation is fairly heavy (annual average of 138.4 cm) and is normally well distributed throughout the year. Direct climatological data are not availabe for the area, but the Mt. Ida Station, located to the northeast at coordinate 34°32′N and 93°36′W (elevation of 212.4m), provides data that should be comparable (table 1). Additional precipitation data obtained from the Big Fork and Athens stations, due north and due south respectively of the area, follow the same general precipitation pattern as that of Mt. Ida.

The majority of the soils belong to either the Carnasaw or Clebit series.[1] The Carnasaw soils (clayey, mixed, thermic Typic Hapludults) are located on gently sloping to steep side slopes. They formed in material weathered from shale of Pennsylvanian age. Solum thickness ranges from 102 to 152 cm. This soil type is well-drained, low in natural fertility and strongly to very strongly acid. Estimated shortleaf pine[2] site index (base age = 50 years) is 18.3 - 21.5 m.

The Clebit soils (loamy-skeletal, siliceous, thermic Lithic Dystrochrepts) are shallow (solum thickness of 25.4 to 50.8 cm), well-drained gravelly fine sandy loam soils that formed in material weathered from sandstone. These soils

[1]Personal correspondence with Mr. Jeff Olson, Soil Conservation Service District office in Mena, AR. The soil survey report for Polk County is incomplete.

[2]Common names utilized throughout the paper are referenced in Appendix Table A, B, and C.

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Table 1.—*Climatological data from Mt. Ida Station (National Oceanic and Atmospheric Administration 1974, 1975, 1976, 1977, 1978)*

Year	Temperature (°C)			No. of frost-free days (°C)	Precipitation (cm)	
	Avg. Annual	Extremes			Total	Depart. from normal
		High	Low			
1974	15.2	41.1	- 9.4	181	186.8	48.2
1975	15.0	39.4	-12.8	173	139.5	0.8
1976	13.9	38.3	-15.0	182	116.4	-22.3
1977	15.3	37.8	-17.2	188	127.9	-10.8
1978	14.4	40.0	-17.2	169	121.2	-17.5
5-year Avg.	14.8	39.3	-14.3	178.9	138.4	- 0.3

are on ridgecrests and upper slopes of both ridges that form the northern and southern boundaries of the Research Natural Area (RNA). Estimated shortleaf pine site index (base age = 50 yrs.) is 12.1 m.

STUDY METHODS

Vegetative analysis used a systematic sampling scheme with nested quadrats as the basic sampling unit. The overstory component (trees > 4.0 cm at 1.3m) was sampled with rectangular quadrats (8 m × 12 m). The smaller tree classes (1.0 to 3.9 cm at 1.3 m) and the shrub component were sampled with 4 m × 6 m quadrats; the herbaceous vegetation was sampled utilizing 1 m × 2 m quadrats.

Sampling units were located by initially establishing a baseline on the northern boundary of the RNA. This baseline was then divided into 100 m units. Each unit thus represented a strip 100 m wide by the width of the entire RNA. These strips were subdivided into 100 m segments creating a series of 100 m × 100 m blocks encompassing the entire area. Location of the sampling unit within these blocks required the selection of 2 random numbers. The first number (from 1-100) defined the distance along the baseline for the beginning of the sample line (and was used for all plots on that line) and the second defined the distance along the sample line due south from the point selected by the first number. The point thus designated by this pair of random numbers located the northeast corner of the nested quadrats. Random numbers that would cause the quadrat location to overlap onto adjacent strips or to adjoining segments were not used. Accordingly, 100 plots were located and sampled. The northeast corner of each odd-numbered sampling unit was permanently marked with metal rods to facilitate future sampling to document successional trends.

Sampling of the overstory component consisted of recording all trees within the specified diameter range by species and diameter at breast height (to nearest mm at 1.3 m). The small tree classes were also tallied by species and diameter. Additionally the tree and shrub species occurring on the 4 m × 6 m quadrat were assigned an estimate of the percentage of the quadrat covered by each species according to the following classes:

Cover Class	*Estimated Cover (%)*
1	≤5
2	6-25
3	26-50
4	51-75
5	76-100

The percentage of ground cover was also estimated for each herbaceous species on the 1 m × 2 m quadrat utilizing these same classes.

In order to define the dominant vegetation of the RBRNA, importance values were calculated for all overstory tree species found on the area. These importance values are the sum of a species' relative frequency, relative density, and relative basal area where:

$$\text{frequency value} = \frac{(\text{no. of plots where species i occurs})}{\text{total no. of plots}} 100$$

$$\text{relative frequency} = \frac{(\text{frequency value for species i})}{\text{total frequency value for all species}} 100$$

$$\text{relative density} = \frac{(\text{no. of stems per ha for species i})}{\text{total no. of stems per ha for all species}} 100$$

$$\text{relative basal area} = \frac{(\text{basal area in } m^2 \text{ per hectare of species i})\ 100}{\text{total basal area in } m^2 \text{ per hectare for all species}}$$

Curtis and McIntosh (1951) proposed these concepts with the premise that species possessing the highest importance values can be used to characterize the dominant vegetation of an area.

As stated earlier, the area has a predominant east-west orientation that creates either north- or south-facing slopes. Empirical evidence quickly identifies different plant associations according to the degree of exposure of the site. Therefore, other approaches to the problem of defining quantitatively the vegetation of the RBRNA were to sort the plots according to their location on either north- or south-facing slopes and by their position on the slope. Six locations were defined (fig. 1). Data were not separated into slope classes (similar percent slope) because the effects of this variable were generally overridden by the potential insolation. Many steeper slopes located on the lower portion (1/3) of the north-facing slope or on midslope positions on the south-facing complicated classification. North-facing plots were relatively moist and often supported the highest species diversity while plots on the south-facing side in the same slope class were very dry.

Calculation of importance values, as developed for the tree component, was not applicable to the shrub or herbaceous component. The dominant species of these components was defined by computing the average percent cover and the relative frequency. The calculation of average percent cover utilized the midpoint of each cover class (2.5, 15.0, etc).

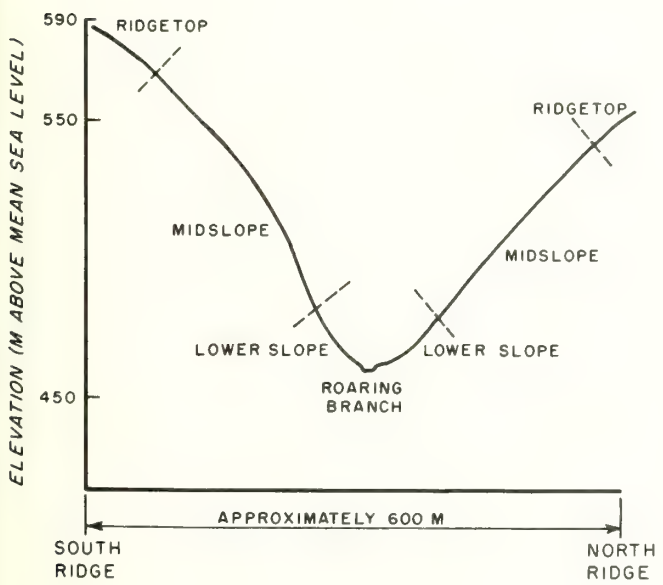

Figure 1—*Cross-section of the RBRNA illustrating the positions on the slope utilized to analyze the vegetative data (line 9, plots 46-50)*

RESULTS

Plant species found in the RBRNA are listed in Appendix Tables A, B, and C. Scientific nomenclature follows Steyermark (1975). All tests of significance throughout this paper are at the 5 percent probability level.

Overstory Component

Twenty-six species were found within the overstory quadrats (table 2). The overall dominant species were white oak, northern red oak, mockernut hickory, black oak, and shortleaf pine. White oak and northern red oak were the only 2 species to occur in more than 50 percent of the plots. In addition to the 5 above-mentioned species, only 4 more species (red maple, blackgum, American beech, and dogwood) occurred on more than 10 percent of the plots. Thirteen species occurred on 5 percent or fewer plots. They comprised only a minor component of the area as a whole but were more important on specific site conditions. White oak not only occurred on a large percentage of the plots but it also averaged over one-third of the basal area of each plot as many of the trees were fairly large (Appendix Table D).

Since all plots basically had either a due north or due south exposure, the data were examined to detect vegetational differences reflective of this difference in potential insolation. An analysis of variance between these 2 aspect classes for the major plot variables indicated a significant difference due to exposure (table 3). The average number of tree species occurring on the overstory quadrats differed significantly with the highest number occurring on the south-facing slope. The average basal area and number of trees per plot for all hickory species were significantly higher on the south-facing slope as were the average total basal area per plot and the average number of trees per plot. Pine basal area per plot and the average number of pine stems per plot were also significantly higher; shortleaf pine only occurred on south-facing plots. Total hardwood basal area per plot was not significantly different, but the average number of hardwood trees per plot differed signifi-

Table 2.—*Importance values of common tree species[1] for the entire RBRNA*

Species	Freq. (%)	Relative freq.	Relative basal area	Relative density	Importance value
white oak	70	19.60	33.83	28.59	82.02
n. red oak	58	16.25	21.64	19.81	57.70
mockernut hickory	43	12.00	9.77	12.25	34.02
black oak	29	8.12	6.99	5.35	20.46
shortleaf pine	21	5.88	8.00	4.30	18.18
red maple	24	6.72	2.46	5.61	14.79
blackgum	20	5.60	4.72	4.16	14.48
American beech	14	3.92	3.96	4.24	12.12
hophornbeam	11	3.08	0.89	2.57	6.54
post oak	8	3.24	1.68	1.11	5.03
serviceberry	9	2.52	0.39	1.91	4.82
dogwood	10	2.80	0.53	1.32	4.65
black hickory	5	1.40	1.28	1.42	4.10
blackjack oak	6	1.68	0.52	1.66	3.86

[1]Species occurring on more than 5 percent of all quadrats.

Table 3.—*Analysis of variance for several plot variables between north- and south-facing slopes on the RBRNA*

Mean plot variable	N-facing slope	S-facing slope	Significance level
No. of herbaceous spp.	1.9	3.0	0.016
No. of shrub/vine spp.	7.9	6.1	0.001
No. of tree spp.	3.2	4.1	0.002
BA/plot for oak spp. (m^2)	0.13	0.11	NS[1]
BA/plot for hickory spp. (m^2)	0.01	0.03	0.005
Total hardwood BA/plot (m^2)	0.17	0.17	NS
BA/plot for pine (m^2)	0.00	0.05	0.000
Total BA/plot (m^2)	0.17	0.21	0.043
No. of trees/plot for oak spp.	4.1	5.0	NS
No. of trees/plot for hickory spp.	1.0	2.9	0.001
Total no. of hardwood trees/plot	7.4	9.6	0.019
No. of trees/plot for pine	0.0	1.0	0.000
Total no. of trees/plot	7.4	10.6	0.001

[1]NS = nonsignificant at 5 percent level.

cantly. Importance values were calculated for each species on each aspect class to identify the dominant species on each class (table 4). Characteristic species for the south-facing slope were northern red oak, white oak, mockernut hickory, shortleaf pine, and black oak. All other species had importance values that were approximately one-third as large as the value for black oak.

The top 3 species on the south-facing slope were also the top 3 on the north-facing side except that white and northern red oak were reversed in order, white oak being the principal species. Its value was almost twice as large as the value for northern red oak and nearly 5 times greater than the third species (mockernut hickory). Shortleaf pine, which did not occur on any of the north-facing plots, was replaced by blackgum as the fourth species in importance. Red maple and American beech followed.

In addition to this sorting of the data by aspect class (or potential insolation), the data were examined to determine any differences in the overstory vegetation according to the position on the slope. As indicated earlier, 6 positions were delineated and compared using analysis of variance (table 5). A substantial number of the variables tested proved to be significantly different among these locations. The number of tree species per plot, the number of hickory (all 3 species combined) trees per plot, hickory basal area per plot, total hardwood trees per plot, and total trees (all species) per plot differed significantly. The highest number of tree species occurred in lower slope positions on both aspect classes with the largest number occurring on the lower slope positions of the south-facing slope. Both hickory basal area and number of stems per plot were higher on the upper and midslope

Table 4.—*Importance values for tree species on each aspect class on the RBRNA*

North-facing aspect		South-facing aspect	
Species	Importance value	Species	Importance value
white oak	100.70	n. red oak	62.25
n. Red oak	54.50	white oak	54.93
mockernut hickory	22.45	mockernut hickory	50.88
blackgum	20.35	shortleaf pine	42.53
red maple	20.12	black oak	21.78
black oak	18.86	blackjack oak	8.07
American beech	15.03	American beech	7.67
hophornbeam	9.02	red maple	7.22
post oak	5.96	blackgum	6.96
dogwood	5.92	black hickory	6.61
serviceberry	4.87	serviceberry	5.71
chinquapin	4.17	sweetgum	4.16
cucumbertree	2.88	red hickory	3.99
dwarf hackberry	2.69	post oak	3.87
black cherry	2.66	hophornbeam	3.57
black hickory	2.19	dogwood	3.21
gum bumelia	2.06	black locust	1.99
witch-hazel	1.50	sparkleberry	1.84
winged elm	1.44	American holly	0.99
black locust	0.96	winged elm	0.95
blackjack oak	0.84	black cherry	0.76
sweetgum	0.84		

Table 5.—*Analysis of variance for major plot variable between positions on the slope for the RBRNA*

Mean plot variable	South-facing aspect			North-facing aspect			Signif. level
	Ridgetop	Midslope	Bottom	Ridgetop	Midslope	Bottom	
No. of herb. spp./plot	3.4	2.7	3.4	3.0	0.9	2.6	0.004
No. of shrub spp./plot	6.1	5.4	5.2	8.1	8.2	6.3	0.002
No. of tree spp./plot	3.5	4.1	5.2	4.2	2.6	3.5	0.000
No. of oak trees/plot	6.2	4.9	2.8	3.2	4.5	4.2	NS[1]
No. of hickory trees/plot	3.4	3.4	1.5	1.8	0.1	2.4	0.000
Total no. of hdwd trees/plot	10.2	8.9	9.9	9.4	6.1	8.6	0.034
Total no. of trees/plot	10.6	10.8	9.9	9.4	6.1	8.6	0.003
Basal area (m^2) of oak/plot	0.16	0.10	0.06	0.09	0.15	0.13	NS
Basal area (m^2) of hickory/plot	0.03	0.03	0.04	0.02	0.01	0.03	0.018
Basal area (m^2) of hdwd/plot	0.19	0.13	0.22	0.16	0.18	0.16	NS
Total basal area (m^2)/plot	0.21	0.22	0.22	0.16	0.18	0.16	NS

[1]NS = nonsignificant at 5 percent level.

south-facing positions. Total trees per plot (all species) were also higher on the 3 south-facing positions than on north-facing positions.

Additionally, importance values for each species on each position on the slope were calculated (table 6). Examination of these values revealed interesting differences in the dominant species on each position. Shortleaf pine only occurred on 2 of the locations, ridge and midslope positions on the south-facing slope. It was the dominant species on this midslope position. White oak ranked as the second, second, fifth, first, first and third species in importance with progression down the south-facing aspect and up the opposite side. Northern red oak was the dominant species on both ridge locations as well as on the lower plots of the south aspect. American beech only occurred in 3 of the locations (lower slope of south aspect, bottom of north aspect, and midslope on the north aspect) but was the third species in importance on the lower slope positions on the southern aspect. Blackgum was found on 4 of the positions and gradually increased in importance to the point that it was the third ranking species on the midslope plots on the northern aspect. Red maple followed a pattern similar to that of blackgum.

Table 6.—*Importance values for each species on each position on the slope within the Roaring Branch RNA*

South-facing slope

Ridgetop		Midslope		Lowerslope	
Species	I.V.	Species	I.V.	Species	I.V.
no. red oak	100.31	shortleaf pine	73.18	no. red oak	49.44
white oak	43.14	white oak	70.03	mockernut	47.81
mockernut	37.30	mockernut	64.47	beech	41.26
shortleaf pine	27.21	no. red oak	38.79	black oak	27.53
black oak	25.15	black oak	21.00	white oak	25.47
black hickory	21.80	serviceberry	9.17	blackgum	23.74
blackjack oak	18.86	blackjack oak	5.67	sweetgum	21.54
red hickory	10.22	post oak	4.83	red maple	19.45
serviceberry	6.35	black locust	4.67	hophornbeam	17.80
sparkleberry	3.52	red hickory	2.32	dogwood	15.76
post oak	3.08	red maple	2.10	holly	5.17
black cherry	3.06	sparkleberry	2.00	winged elm	4.94
		blackgum	1.77		

North-facing

Lowerslope		Midslope		Ridgetop	
Species	I.V.	Species	I.V.	Species	I.V.
white oak	58.54	white oak	151.92	no. red oak	94.28
mockernut	40.68	no.red oak	51.57	mockernut	38.92
beech	19.37	blackgum	27.99	white oak	34.06
black	30.90	red maple	27.45	post oak	24.50
no. red oak	30.66	black oak	10.45	hophornbeam	17.60
red maple	24.42	serviceberry	6.68	black cherry	13.72
blackgum	21.80	chinquapin	6.29	dwarf hackberry	13.71
hophornbeam	16.87	mockernut	5.34	black oak	11.94
dogwood	11.18	beech	4.99	gum bumelia	11.28
cucumbertree	9.20	dogwood	3.95	red maple	5.13
chinquapin	3.74	black locust	1.77	serviceberry	4.34
post oak	3.71	witch-hazel	1.58	winged elm	4.24
witch-hazel	2.59			blackjack oak	3.75
serviceberry	2.19				
sweetgum	2.12				
winged elm	2.09				

Shrub Component

The shrub component of the vegetation of the RBRNA included woody vines, shrubs, and stems of overstory trees that were less than 4.0 cm at 1.3 m. Fifty-one species were sampled in the shrub quadrats; 7 were vines, 13 were shrubs and the remainder were species also sampled in the overstory quadrats. In addition, 7 other shrub and vine species were found in the RNA but were not found in any of the plots (Appendix Table B).

Twenty-six of these species occurred on at least 5 percent of the plots (table 7): 19 of these were overstory component species. Mean percent cover for all species was low: none exceeded 11 percent although several were locally abundant (table 7—see highest percent cover). Lowbush blueberry, witch-hazel, white oak, mountain azalea, northern red oak, red maple, sparkleberry, and hophornbeam were the only species with mean percent cover greater than 2 percent. In frequency of occurrence, lowbush blueberry occurred on the largest number of plots (65) followed by white oak, witch-hazel, and northern red oak.

Examination of the shrub quadrat data by aspect classes (north-facing versus south-facing aspect) revealed that 10 species were significantly different regarding their presence on these two classes (chi-square 2 × 2 contingency table at 0.05 level). Seven of these species were overstory component species. Red maple, American beech, witch-hazel, white oak, mountain azalea,

Table 7.—*Shrub species that occurred on at least 5 percent of the quadrats on the RBRNA*

Species	Freq. (%)	Relative freq.	Average % cover	Highest % cover
lowbush blueberry	65	9.15	10.8	87.5
white oak	56	7.89	5.1	62.5
witch-hazel	51	7.14	9.2	87.5
n. red oak	49	6.90	3.8	37.5
sparkleberry	37	5.21	3.1	37.5
red maple	36	5.04	3.3	37.5
serviceberry	34	4.79	2.0	37.5
mountain azalea	28	3.94	4.7	62.5
mockernut hickory	28	3.94	1.6	15.0
black oak	28	3.94	1.2	15.0
blackgum	26	3.66	1.0	15.0
glaucous greenbriar	24	3.38	0.8	15.0
poison-ivy	21	2.95	2.0	37.5
sassafras	21	2.95	1.0	15.0
black locust	21	2.95	0.6	15.0
hophornbeam	19	2.53	2.3	37.5
Virginia creeper	19	2.53	1.2	37.5
American beech	18	2.52	1.3	37.5
black cherry	11	1.55	0.6	37.5
dogwood	10	1.41	1.3	37.5
muscadine	10	1.41	0.8	62.5
chinquapin	9	1.27	0.5	15.0
shortleaf pine	8	1.13	1.0	37.5
blackjack oak	7	0.98	1.0	37.5
common greenbriar	6	0.84	0.6	37.5
black hickory	6	0.84	0.5	15.0

glaucous greenbriar and sassafras were significantly associated with the north-facing slope. Shortleaf pine, mockernut hickory, and blackjack oak were the only species significantly associated with the southern aspect.

Sorting the data by position on the slope (fig. 1) revealed some interesting vegetative features of the area. Examination of this data, utilizing the chi-square test of independence, found sixteen species to be significantly different between the positions on the slope. Of the species that are only found as part of the understory, lowbush blueberry, witch-hazel, sparkleberry, mountain azalea, glaucous greenbriar, poison ivy, and Virginia creeper were significantly different. Tree species that were sampled by the shrub quadrat that were significantly different between location classes were: shortleaf pine, blackjack oak, white oak, red maple, blackgum, sassafras, hophornbeam, flowering dogwood, and American beech.

These data and table 8 which illustrates frequency of each species by location indicate that the dominant shrub species of each location would be:

Location	*Species*
South-facing ridgetop	lowbush blueberry, Virginia creeper, sparkleberry, shortleaf pine, blackjack oak
South-facing midslope	lowbush blueberry, white oak, sparkleberry, blackjack oak, shortleaf pine
South-facing lower slopes	poison ivy, witch-hazel, hophornbeam, blackgum, dogwood, Virginia creeper
North-facing lower slopes	witch-hazel, American beech, lowbush blueberry, white oak, hophornbeam, red maple
North-facing midslope	witch-hazel, lowbush blueberry, white oak, mountain azalea, red maple, sparkleberry
North-facing ridgetop	lowbush blueberry, Virginia Creeper, white oak, poison ivy, red maple, hophornbeam

Table 8.—*Frequency of occurrence of shrub species by position on slope (percent of plots sampled in each location)*

Species	Position on slope					
	South-facing slope			North-facing slope		
	Ridgetop	Mid	Lower	Ridgetop	Mid	Lower
lowbush blueberry	69.2	72.2	25.0	47.1	90.9	45.5
witch-hazel	7.7	0.0	62.5	82.4	93.9	9.1
mtn. azalea	0.0	0.0	12.5	29.4	63.6	9.1
glaucous greenbriar	15.4	0.0	25.0	29.4	39.4	9.1
poison-ivy	7.7	5.6	75.0	47.1	9.1	27.3
Virginia creeper	62.5	0.0	50.0	23.5	6.1	45.5
sparkleberry	38.5	38.9	12.5	11.8	54.5	18.2
white oak	15.4	55.6	37.5	47.1	87.9	45.5
red oak	7.7	11.1	37.5	47.1	57.6	27.3
blackgum	7.7	11.1	62.5	29.4	36.4	9.1
sassafras	15.4	0.0	0.0	29.4	36.4	18.2
hophornbeam	7.7	5.6	62.5	47.1	6.1	27.3
Amer. beech	0.0	5.6	25.0	70.6	15.2	0.0
flowering dogwood	0.0	0.0	50.0	17.6	9.1	0.0
blackjack oak	23.1	16.7	0.0	0.0	0.0	9.1
shortleaf pine	30.8	11.1	0.0	0.0	0.0	9.1
No. of plots	13	38	8	17	33	11

Several species were consistently found only on certain locations and were an important facet of that vegetative community. These include dwarf bumelia, fragrant sumac, hoptree, and Carolina buckthorn which were found only on the very tops of both the north and south ridge. Strawberry bush and deciduous holly were found only on lower slope plots.

Herbaceous Component

Forty-three herbaceous species were identified within the 1m × 2m quadrats (Appendix Table C). Area-wide, no single species exhibited a very high average percent cover or high frequency of occurrence (table 9). Narrow-leaf panicum, poverty grass, beggars-lice, bluestem goldenrod, and pussy's toes were the only species to exceed 1 percent average cover. Poverty grass, with the highest relative frequency, only occurred on 23 plots; it was followed by narrow-leaf panicum, bluestem goldenrod, beggars-lice, anomalus aster, pussy's toes and mountain mint. These were the only species to occur on at least 10 percent of the quadrants. Nine additional species occurred on 5 percent or greater of the plots. Fourteen species had only a single occurrence on the quadrats.

DISCUSSION

Ecological Status and Vegetative Description

The Roaring Branch RNA is a diverse area in both topography and vegetation. The area is comprised of several major plant communities which are created by the east-west parallel ridges that form the northern and southern boundary and by the influence of Roaring Branch itself.

As indicated, the topographic orientation results in either a north- or south-facing aspect for all sites on the area. The south-facing side is undergoing a progressive development toward a steady-state system. Its current status is, therefore, one typified by transition. Aerial photos of the area, as well as casual observation, indicate that this slope should be a shortleaf pine type (Ferguson 1968), but this was not borne out by the data. The dominant species (from 41 sample quadrats) classify this site as a northern red oak-white oak-mockernut hickory-shortleaf pine community. Examination of average basal area per plot shows shortleaf being rated as the second most important species with northern red oak being the principal dominant.

The pine stems on the area are generally large but scattered. Less than 50 percent of the overstory quadrats sampled on this slope (20 of 41) contained shortleaf pine. These individuals are of advanced age and are approaching their biological maturity (150+ years). As they age and mortality increases, the pine component will gradually be replaced, barring any major disturbance such as a wildfire. Sufficient pine reproduction does not exist to maintain this species' dominance in the stand. It ranks 23rd in frequency of occurrence on the shrub quadrats. In addition to this lack of pine reproduction, the

Table 9.—*Herbaceous species occurring on at least 5 percent of the quadrats on the RBRNA*

Species	Freq. (%)	Relative freq.	Average % cover	Highest % cover
poverty grass	23	10.31	1.7	62.5
narrow-leaf panicum	21	9.42	1.7	87.5
beggars-lice	17	7.62	1.5	37.5
bluestem goldenrod	17	7.62	1.3	87.5
anomalus aster	14	6.28	0.5	15.0
pussy's toes	12	5.38	1.0	37.5
mountain mint	10	4.48	0.8	15.0
prairie sunflower	9	4.03	0.6	37.5
common panic grass	8	3.59	0.4	15.0
panic grass	8	3.59	0.4	15.0
mountain hustonia	7	3.14	0.2	2.5
skullcap	7	3.14	0.2	2.5
bedstraw	6	2.69	0.4	15.0
broom sedge	6	2.69	0.3	15.0
wild yam	5	2.24	0.2	15.0
common lespedeza	5	2.24	0.2	15.0

area around the pine stems is largely occupied by hardwoods and woody shrubs that will prevent the re-establishment of pine on sites currently occupied by pines. The characteristic shrub component is a blueberry complex while the herbaceous component is typically a panic grass-beggars lice association.

The north-facing aspect, however, represents a fairly stable ecosystem. The principal overstory species, white oak, northern red oak, mockernut hickory, and blackgum, are also dominant in the shrub component. These species are therefore replacing themselves and will maintain their dominant positions through time, barring major disturbance. When all 3 vegetative components are considered, this side of the area is characterized as an oak-hickory complex with a blueberry-azalea-oak-chinquapin shrub component and panic grass-aster herbaceous component.

The ridgetop communities (northern and southern boundaries) are noticeably different from midslope positions on both aspects and somewhat different between ridges. The dominant overstory species on the north ridge are white oak, northern red oak, mockernut hickory, shortleaf pine and black oak. Black hickory and blackjack oak are also characteristic overstory species. Dominant shrub species are hoptree, fragrant sumac and hophornbeam while a prairie sunflower-panic grass-beggars-lice association dominates the herbaceous component. Also, frequently occurring on this position is purple cress, a species currently on the threatened species list for Arkansas (Arkansas Dept. of Planning 1974).

The southern ridge (mostly north-facing), with more exposed rock and shallower soils, is noticeably drier than the northern ridge. Dominant overstory species are northern red oak, mockernut hickory, white oak, and post oak. Common associates include hophornbeam, black cherry, dwarf hackberry and gum bumelia. Common shrub species are lowbush blueberry, bramble, and black locust. Typical herbaceous species were several panic grasses, poverty grass, prairie sunflower, bedstraw, and beggars-lice.

The south-facing midslope positions are characterized by a shortleaf pine-white oak-mockernut hickory complex with northern red oak and black oak as common associates. Increment core samples illustrated that 2 basic age classes exist within the main canopy layer: the shortleaf pines are 100+ years hile the hardwood component is considerably younger (50–75 years). These age differences further reflect the transition occurring. The shrub component is dominated by a blueberry complex plus transgressives of the principal overstory species. Frequently encountered herbaceous species are several panic grasses, poverty grass, and several species of beggars-lice.

Midslope positions on the north-facing aspect are dominated by widely scattered, large stems of white oak, northern red oak, and blackgum. These trees are essentially the same age as the shortleaf pines on the south-facing side (100+ years). Heart rot or hollow boles made exact age difficult to determine. Common overstory associates include red maple, blackgum, serviceberry, and chinquapin. It should be noted that all stems of chinquapin that were found were sprouts from stems that had died from the chestnut blight. Principal shrub species were lowbush blueberry, mountain azalea, witch-hazel, white oak, sparkleberry, red maple, and chinquapin. Common herbaceous species were pussy's toes, beggars-lice, several panic grasses, mountain mint, anomalus aster, and mountain hustonia. One species (rattlesnake plantain) was found that is currently on the threatened species list (Arkansas Dept. of Planning 1974).

The lower slope positions on both aspects were similar in species composition. The 5 most important species were the same, but the order of white oak and northern red oak was reversed. Perhaps the characteristic species for this portion of the area would be American beech, sweetgum, cucumbertree and dogwood rather than the dominant northern red oak-white oak-mockernut hickory complex. These lower slopes are adjacent to Roaring Branch which is spring fed and seldom, if ever, goes dry. It did maintain free-flowing surface water during the entire summer of 1980, which reputedly was among the

driest years in Arkansas on record. Species richness in all vegetative components is greatest on these lower slope positions. Several woody species are endemic to these slopes including cucumbertree, sweetgum, American holly, basswood, deciduous holly, and strawberry bush. Common herbaceous species were dwarf wild iris, beech drops, panic grasses, wild yam and several fern species (cinnamon fern, marginal shield fern, and Christmas fern). Two species, Indian cucumberoot and wake robin, are currently on the threatened plant species list for Arkansas (Arkansas Dept. of Planning 1974).

Wildlife Habitat Value

Although the Roaring Branch RNA is relatively small, its remote location and freedom from recent disturbance make it a prime wildlife area for species associated with old-growth, mixed hardwood-pine communities. The overstory is made up of a variety of both hard and soft mast-producing species. The 2 most important species (highest relative frequence and density) on the area are white oak and northern red oak, and the oaks as a group make up 65 percent of the overstory. Other hard mast producers, relatively abundant (occurring in 20 percent or more of the plots), include mockernut hickory, black oak, shortleaf pine, red maple and blackgum.

The primary producer of soft mast is lowbush blueberry, occuring on 65 percent of the sample lots at an average cover of 11 percent. Other important soft mast producers include sparkleberry, service berry, glaucous greenbriar, poison ivy, black cherry, dogwood, and muscadine, all of which occur in 10 percent or more of the sample plots. The species diversity in both soft and hard mast producers assures a relatively stable mast component which is an important wildlife habitat value.

A variety of species is also present in the Roaring Branch RNA herbaceous community, but sufficient quantity is lacking. Only 7 species occur on 10 percent or more of the study plots, and only 2 of these (narrow-leaf panicum and beggars-lice) are generally considered important wildlife plants. In addition to low frequency of occurrence, the average percent cover for all species is below 2 percent. Narrow-leaf panicum and beggars-lice, however, are important in some localized areas, reaching maximum cover rating of 88 and 38 percent respectively. The dominance of a closed overstory and the presence of a large shrub component reduce solar insolation below levels sufficient to support significant herbaceous growth. The absence of herbaceous ground cover must be considered a negative habitat value.

The composite wildlife habitat value of the Roaring Branch RNA is good. The remoteness of the area and its protected status enhance the current and future wildlife value. With the presence of an important, relatively stable mast component, this old-growth, mixed hardwood area is valuable habitat for many mid- to late-successional wildlife species. For early successional wildlife, the value and use are much more limited and would, to a large degree, depend on surrounding habitat conditions.

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Appendix

Appendix Table A.—*Tree species found on the Roaring Branch Research Natural Area (*indicates those species found outside sample quadrats)*

Family	Scientific Name	Common Name
Pinaceae	*Pinus echinata* Mill.	shortleaf pine
Cupressaceae	**Juniperus virginiana* L.	e. redcedar
Juglandaceae	*Carya ovalis* (Wang.) Sarg.	red hickory
	Carya texana Buckl.	black hickory
	Carya tomentosa Nutt.	mockernut hickory
Corylaceae	*Ostrya virginiana* (Mill.) K. Koch	hophornbeam
Fagaceae	*Fagus grandifolia* Ehrh.	American beech
	Castanea ozarkensis Ashe	Ozark chinquapin
	Quercus alba L.	white oak
	Quercus marilandica Muenchh.	blackjack oak
	**Quercus prinoides* Willd.	chinkapin oak
	Quercus rubra L.	n. red oak
	Quercus stellata Wang.	post oak
	Quercus velutina Lam.	black oak
Ulmaceae	*Celtis tenuifolia* Nutt.	dwarf hackberry
	Ulmus alata Michx.	winged elm
Magnoliaceae	*Magnolia acuminata* L. var *acuminata*	cucumbertree
Lauraceae	**Sassafras albidum* (Nutt.) Nees	sassafras
Hamamelidaceae	*Hamamelis virginiana* L.	witch-hazel
	Liquidambar styraciflua L.	sweetgum
Rosaceae	*Amelanchier arborea* (Michx.f.) Fern	serviceberry
	**Prunus mexicana* S. Wats	Mexican plum
	Prunus serotina Ehrh.	black cherry
Leguminosae	**Cercis canadensis* L.	e. redbud
	Robinia pseudoacacia L.	black locust
Aquifoliaceae	*Ilex opaca* Ait.f.	American holly
Aceraceae	*Acer* rubrum L.	*red maple*
	**Acer rubrum* var *Drummondii* (H.&.A.) Sarg.	*Drummond red maple*
	**Acer saccharum* Marsh	*sugar maple*
Tiliaceae	**Tilia americana* L.	basswood
Cornaceae	*Cornus florida* L.	flowering dogwood
	Nyssa sylvatica Marsh.	blackgum
Ericaceae	*Vaccinium arboreum* Marsh.	*sparkleberry*
Sapotaceae	*Bumelia lanuginosa* (Michx.) Pers. var *albicans*	*gum bumelia*
Ebenaceae	**Diospyros virginiana* L. Sarg.	*persimmon*

Appendix Table B.—*Listing of shrub and vine species found on the Roaring Branch Research Natural Area (*indicates those species found outside sample quadrats)*

Family	Scientific Name	Common Name
Liliaceae	*Smilax glauca* Walt.	glaucous greenbriar
	Smilax rotundifolia L.	common greenbriar
Saxifragaceae	*Ribes missouriense* Nutt.	Missouri gooseberry
Rosaceae	**Crataegus marshallii* Egglest.	parsley hawthorn
	Rubus spp. L.	bramble
Rutaceae	*Ptelea trifoliata* L.	hoptree
Anacardiaceae	*Rhus aromatica* Ait.	fragrant sumac
	Rhus copallina L. var *latifolia* Engler	shining sumac
	**Rhus glabra* L. var *glabra*	smooth sumac
	Rhus radicans L.	poison ivy
Aquifoliaceae	*Ilex decidua* Walt.	deciduous holly
Celastraceae	*Euonymus americanus* L.	strawberry-bush
Hippocastanaceae	**Aesculus glabra* Willd.	yellow buckeye
Rhamnaceae	*Rhamnus caroliniana* Walt.	Carolina buckthorn
Vitaceae	*Parthenocissus quinquefolia* (L.) Planch.	Virginia creeper
	**Vitis aestivalis* Michx.	summer grape
	Vitis rotundifolia Michx.	muscadine
Hypericaceae	*Ascyrum hypericoides* L.	St. John's wort
Araliaceae	**Aralia spinosa* L.	devil's walkingstick
Ericaceae	*Lyonia mariana* (L.) DC.	staggerbush
	Rhododendron roseum f. *albidum* Steyer.	white mountain azalea
	Vaccinium stamineum L.	deerberry
	Vaccinium vacillans Torr.	lowbush blueberry
Verbenaceae	*Callicarpa americana* L.	French mulberry
Caprifoliaceae	**Lonicera flava* Sims.	yellow honeysuckle
	Lonicera sempervirens L.	trumpet honeysuckle
	**Symphoricarpus orbiculatus* Moench.	coral berry

Appendix Table C.—*Listing of all herbaceous species found in the Roaring Branch Research Natural Area (*indicates those species found outside sample quadrats)*

Family	Scientific Name	Common Name
Polypodiaceae	**Adiantum pedatum* L. var *pedatum*	maidenhair fern
	Asplenium platyneuron (L.) Oakes	ebony spleenwort
	**Athyrium felix-femina* (L.) Roth.	lady fern
	Dryopteris marginalis (L.) Gray	marginal shield fern
	Osmunda cinnamomea L.	cinnamon fern
	**Polystichum acrostichoides* (Michx.) Schott	Christmas fern
	**Pteridium aquilinum* (L.) Kuhn	bracken fern
	Thelypteris hexagonoptera (Michx.) Weath	broad beech fern
Gramineae	*Andropogon virginicus* L.	broom sedge
	**Bromus purgans* L.	brome grass
	Danthonia spicata (L.) Beauv.	poverty grass
	**Hystrix patula* Moench	bottlebrush
	Muhlenbergia tenuiflora (Willd.) B.S.P.	muhly grass
	Panicum commutatum Schultes var *communtatum*	common panic grass
	Panicum latifolium L.	wide-leaf panicum
	Panicum linearifolium Scribn. var *linearifolium*	narrow-leaf panicum
	**Panicum oligosanthes* Schultes	panicum grass
	Sporobolus spp. R.Br.	dropseed
Cyperaceae	**Carex* spp. L.	sedge
	Scleria spp. Bergius	nut rush
Araceae	**Arisaema atrorubens* (Ait.) Blume	jack-in-the-pulpit
Commelinaceae	**Tradescantia ohiensis* Raf.	spiderwort

Appendix Table C.—*Listing of all herbaceous species found in the Roaring Branch Research Natural Area (*indicates those species found outside sample quadrats) — Continued*

Family	Scientific Name	Common Name
Liliaceae	*Amianthium muscaetoxicum* (Walt.) Gray	fly-poison
	Medeola virginiana L.	Indian cucumber-root
	Smilacina racemosa (L.) Desf.	false spikenard
	**Trillium* spp. L.	wake robin
Amaryllidaceae	*Dioscorea quaternata* (Walt.) J.F. Gmel	wild yam
	**Dioscorea villosa* L.	yam
Iridaceae	*Iris cristata* Ait.	dwarf wild iris
Orchidaceae	**Goodyera pubescens* (Willd.) R.Br.	rattlesnake plantain
Aristolochiaceae	*Aristolochia serpentaria* L.	Virginia snakeroot
Caryophyllaceae	**Silene virginicus* L.	fire pink
Cruciferae	**Streptanthus maculatus* Nutt.	purple cress
Rosaceae	**Rosa carolina* L.	pasture rose
Leguminosae	*Baptisia leucophaea* Nutt.	wild indigo
	**Desmodium glutinosum* (Muhl.) Wood	beggars-lice
	**Desmodium laevigatum* (L.) DC.	smooth beggars-lice
	Desmodium marilandicum (L.) DC.	beggars-lice
	Desmodium nudiflorum (L.) DC.	beggars-lice
	Desmodium rotundifolium DC.	round-leaf tick trefoil
	Lespedeza virginica (L.) Britt.	common lespedeza
Oxalidaceae	*Oxalis* spp. L.	wood sorrel
Euphorbiaceae	*Acalypha* spp. L.	three-seeded mercury
Violaceae	**Viola* pedata L.	bird's-foot violet
	Viola spp. L.	violet
Passifloraceae	*Passiflora lutea* L. var *glabriflora* Fern	passion-flower
Cactaceae	**Opuntia compressa* (Salisb.) Macbr.	prickly pear
Umbelliferae	**Osmorhiza claytonia* (Michx.) Clarke	sweet cicely
	Sanicula canadensis L.	black snakeroot
	**Sanicula gregaria* Bicknell	sanicle
	**Taenidia integerrima* (L.) Drude	yellow pimpernel
	**Thaspium barbinode* (Michx.) Nutt. var *barbinode*	meadow parsnip
Asclepiadaceae	**Asclepias quadrifolia* Jacq.	milkweed
Boraginaceae	**Cynoglossum virginianum* L.	wild comfrey
Labiatae	**Monarda Russeliana* Nutt.	horsemint
	Pycnanthemum spp. Michx.	mountain mint
	Scutellaria elliptica Muhl.	hairy skullcap
Schrophulariaceae	**Pedicularis canadensis* L.	wood betony
	**Penstemon tubaeflorus* Nutt.	beard tongue
Orobanchaceae	*Epifagus virginiana* (L.) Bart	beech drops
Rubiaceae	*Galium obtusum* Bigel. var *obtusum*	bedstraw
	Hustonia longifolia var *tenuifolia* (Nutt.) Wood	mountain hustonia
Campanulaceae	**Campanula americana* L.	bellflower
Compositae	*Antennaria plantaginifolia* (L.) Hook.	pussy's toes
	Aster anomalus Engelm.	anomalus aster
	Aster patens Ait.	spreading aster
	**Erigeron philadelphicus* L.	Philadelphia fleabane
	Erigeron strigosus Muhl.	daisy fleabane
	Helianthus lactiflorus Pers.	prairie sunflower
	Hieracium gronovii L.	hawkweed
	**Lactuca canadensis* L.	wild lettuce
	Liatris squarrosa var *squarrosa* (L.) Michx.	blazing star
	Prenanthes spp. L.	rattlesnake root
	Solidago arguta Ait.	goldenrod
	Solidago flexicaulis L.	bluestem goldenrod

Appendix Table D.—*Stand table (trees/ha) for tree species on the RBRNA*

Dia. (cm)	shortleaf pine	mockernut hickory	northern red oak	white oak	blackgum	post oak	black oak	Amer. beech	black hickory	winged elm	witch-hazel	sweetgum	Amer. holly
4.0- 6.0	5.2	32.3	10.4	38.5	8.3	3.1	3.1	13.5	2.1	2.1	3.1	...	...
6.1- 8.0	3.1	32.3	20.8	34.4	4.2	1.0	4.2	6.2	9.4	2.1	...	...	...
8.1-10.0	1.0	30.2	20.8	27.1	3.1	1.0	6.2	3.1	2.1	...	...	1.0	...
10.1-12.0	3.1	12.5	21.2	18.8	...	...	6.2	1.0	1.0	1.0	...	1.0	2.1
12.1-14.0	4.2	16.7	11.4	10.4	2.1	...	3.1	...	2.1	...	...	...	...
14.1-16.0	5.2	10.4	24.0	6.2	1.0	2.1	5.2	1.0	1.0	...	...	1.0	...
16.1-18.0	...	5.2	10.4	8.3	...	...	7.3	1.0	...	...	...	...	...
18.1-20.0	3.1	5.2	14.6	7.3	1.0	1.0	4.2	...	1.0	...	...	...	...
20.1-22.0	1.0	1.0	15.6	7.3	1.0	...	1.0	...	1.0	...	...	...	...
22.1-24.0	2.1	1.0	7.3	6.2	...	...	...	1.0	...	...	...	...	...
24.1-26.0	1.0	3.1	4.2	4.2	1.0	...	...	...	...	...	...	...	...
26.1-28.0	3.1	1.0	...	3.1	1.0	...	...	...	...	...	...	...	...
28.1-30.0	...	...	5.2	3.1	1.0	1.0	1.0	...	...	...	...	1.0	...
30.1-32.0	...	1.0	2.1	8.3	1.0	1.0	...	...	...	...	...	2.1	...
32.1-34.0	2.1	1.0	1.0	5.2	...	...	2.1	...	...	...	...	...	...
34.1-36.0	1.0	...	1.0	7.3	1.0	...	...	...	...	...	...	...	...
36.1-38.0	1.0	1.0	...	2.1	1.0	...	2.1	...	...	...	...	...	...
38.1-40.0	1.0	...	1.0	4.2	...	...	...	...	...	...	...	...	...
40.1-42.0	...	...	1.0	...	...	...	1.0	...	...	...	...	...	...
42.1-44.0	1.0	...	1.0	4.2	1.0	...	...	...	...	...	...	...	...
44.1-46.0	...	...	1.0	1.0	1.0	...	...	...	...	...	...	...	...
46.1-48.0	1.0	...	...	3.1	...	...	...	...	...	...	...	...	...
48.1-50.0	1.0	...	...	...	...	...	...	...	...	...	...	...	...
50.1-52.0	...	...	...	1.0	...	...	...	1.0	...	...	...	...	...
52.1-54.0	...	...	...	...	...	...	...	...	...	...	...	...	...
54.1-56.0	...	...	...	...	...	...	...	...	...	...	...	...	...
56.1-58.0	...	...	...	...	...	...	...	...	...	...	...	...	...
58.1-60.0	...	...	...	...	...	...	...	...	...	...	...	...	...
60.0	1.0	...	...	1.0	...	...	...	1.0	...	...	...	...	...

Appendix Table D.—*Stand table (trees/ha) for tree species on the RBRNA—Continued.*

Dia. (cm)	gum bumelia	sparkle berry	cucumber tree	hophorn beam	red maple	chinquapin	blackjack oak	service berry	black cherry	dwarf hackberry	black locust	dogwood	red hickory
4.0- 6.0	2.1	4.2	1.0	16.7	14.6	1.0	5.2	13.5	3.1	4.2	...	7.3	2.1
6.1- 8.0	1.0	...	2.1	11.4	11.4	1.0	4.2	3.1	...	...	1.0	4.2	1.0
8.1-10.0	...	...	1.0	2.1	6.2	1.0	...	1.0	...	...	1.0	3.1	1.0
10.1-12.0	...	...	...	1.0	6.2	...	...	1.0	1.0	1.0	1.0	...	1.0
12.1-14.0	...	...	3.1	3.1	4.2	...	1.0	...	...	...	...	...	...
14.1-16.0	...	...	...	...	3.1	...	...	...	...	...	...	...	2.1
16.1-18.0	...	...	...	...	...	...	...	...	...	...	...	...	...
18.1-20.0	...	...	...	...	...	...	...	...	...	...	...	...	...
20.1-22.0	...	...	...	...	...	...	...	...	...	...	...	...	...
22.1-24.0	...	...	...	...	...	...	...	...	...	...	...	...	...
24.1-26.0	...	...	...	...	...	1.0	...	...	...	...	...	...	...
26.1-28.0	...	...	...	...	...	...	...	...	...	...	...	...	...
28.1-30.0	...	...	...	...	...	...	...	...	...	...	...	...	...
30.1-32.0	...	...	...	...	...	...	...	...	...	...	...	...	...
32.1-34.0	...	...	...	...	...	...	...	...	...	...	...	...	...
34.1-36.0	...	...	...	...	...	...	...	...	...	...	...	...	...
36.1-38.0	...	...	...	...	...	...	...	...	...	...	...	...	...
38.1-40.0	...	...	...	...	...	...	...	...	...	...	...	...	...
40.1-42.0	...	...	...	...	...	...	...	...	...	...	...	...	...
42.1-44.0	...	...	...	...	...	...	...	...	...	...	...	...	...
44.1-46.0	...	...	...	...	...	...	...	...	...	...	...	...	...
46.1-48.0	...	...	...	...	...	...	...	...	...	...	...	...	...
48.1-50.0	...	...	...	...	...	...	...	...	...	...	...	...	...
50.1-52.0	...	...	...	...	...	...	...	...	...	...	...	...	...
52.1-54.0	...	...	...	...	...	...	...	...	...	...	...	...	...
54.1-56.0	...	...	...	...	...	...	...	...	...	...	...	...	...
56.1-58.0	...	...	...	...	...	...	...	...	...	...	...	...	...
58.1-60.0	...	...	...	...	...	...	...	...	...	...	...	...	...
60.0	...	...	...	...	...	...	...	...	...	...	...	...	...

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Provides details of an area that probably represents a natural ecological succession relatively undisturbed by man. The area includes unique vegetative types.

United States
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Forest Service

**Southern Forest
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Long-Term Impact of Hardwood Control Treatments in Mature Pine Stands

Michael D. Cain

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SUMMARY

Understory and midstory hardwoods were intensively controlled by prescribed fire or chemical treatments between 1954 and 1961 in a mature loblolly (*Pinus taeda* L.) and shortleaf (*P. echinata* Mill.) pine stand in south Arkansas. In 1983, hardwood basal area on treated plots was materially less than that on untreated plots. Chemical application was more effective than prescribed burning for reducing hardwood stems per acre during treatment, and this reduction was maintained for 23 years after treatments ended. Seven years of intensive hardwood control did not significantly increase the long-term cubic-foot or board-foot volume growth per acre of the overstory pine component when compared to growth on untreated plots.

Long-Term Impact of Hardwood Control Treatments in Mature Pine Stands

Michael D. Cain

INTRODUCTION

The understory of the loblolly—shortleaf pine *(Pinus taeda L.—P. echinata* Mill.) type in the Upper Coastal Plain is characterized by an abundance of hardwood species that may number more than 10,000 stems per acre. These hardwoods can reduce the growth potential of overstory pines (Grano 1970a) and impede the establishment of natural pine regeneration after overstory pines are cut or die (Mann 1973).

A number of researchers have assessed the short-term effects of understory hardwood removal on growth of overstory loblolly and shortleaf pine. Results have been almost equally divided between positive (Bower and Ferguson 1968, Grano 1970a, Clason 1978) and negative (Lange 1951, McClay 1955, Russell 1961). such contradictory results were probably influenced by soil, site, stand, and weather variability, as well as the period of time during which the assessment was made. Although results after 5 to 15 years may provide valuable information, those time intervals are relatively short when placed in the context of a managed forest.

Although overstory pine growth response is a worthwhile objective of understory vegetation management, hardwood reinvasion following treatment is also an important consideration. Short-term studies often fail to examine hardwood reinvasion, because it is a long-term consequence of vegetation manipulations. Differences in reinvasion rates may vary significantly between alternative vegetation management treatments and lead to differences in pine growth and development. Such differences may result in one type of treatment being favored over others by forest land managers.

METHODS

Study Area

The study was located on the Crossett Experimental Forest in south Arkansas. Soil on the study area is predominantly Providence (Typic Fragiudalfs) silt loam with an impervious layer at 18 to 40 inches that impedes internal drainage (USDA 1979). The soil has a site index of 85 to 90 feet for loblolly pine at base age 50 years. Annual precipitation averages 55 inches, with extremes being wet winters and dry autumns.

Management History and Treatments

In 1953, a hardwood control study was initiated in a 49-year-old managed stand of old-field loblolly and shortleaf pine to determine if removal of understory hardwoods would materially increase the volume growth of overstory pines. In the study, six ¼-acre plots were established with a 33-foot-wide isolation strip around each. All plots were thinned to between 75 and 80 square feet of pine basal area per acre in February 1954. Thinning was done from below and favored loblolly pine. Treatments were begun in 1954, and the study was terminated in 1961. Three treatments were assigned at random within two replications. The only documented treatment that may have affected hardwood density prior to study initiation was a prescribed burn in 1942. That burn included all three treatment plots in one replication of the hardwood control study, but none in the other replication.

Treatments in the hardwood control study were:

Control—There was no disturbance or treatment of hardwoods after the 1954 thinning.

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Burn—Winter burn in 1954, to be followed by annual summer burns if the fuel supply and weather permitted.

Chemical—Hardwoods ≥6 feet in height were cut and their stumps treated with a 5-percent solution of 2,4,5,-T in diesel oil in May 1954. The foliage of smaller hardwoods was sprayed with a 1-percent mixture of 2,4,5-T in water. Touch-up spraying was applied as needed to effect complete hardwood exclusion.

Treatment data on the prescribed burns are given in table 1. Between November 1942 and February 1980, there were seven prescribed fires on the "burn" plots—one in 1942 prior to the hardwood control study, four during the study from 1954 through 1960, and two (1967 and 1980) after the study closed. After study initiation in 1954, the plan to burn annually was never achieved because of the scarcity or uneven distribution of ground fuel in combination with unfavorable weather conditions. By the summer of 1960, hardwood sprouting was vigorous on burned plots, despite four prescribed fires (fig. 1).

The prescribed fire in 1967 was to maintain the burn treatment for demonstration purposes. Because of the fuel buildup and time of year, the burn was extremely hot. As a result, several overstory pines subsequently died and were removed in salvage cuts. The 1980 burn was for fuel hazard reduction over the entire 40-acre compartment in which the hardwood control study was located.

On the chemically treated plots, hardwood elimination was easy to maintain by light touch-up foliar spraying with a 1-percent 2,4,5-T solution in water (fig. 2). The initial chemical treatment was in May 1954 with subsequent chemical applications in June 1955, June 1956, and June 1958.

Only two overstory pines died over the entire study between 1954 and 1961. One of those pines was on a chemically treated plot and the other was on a control plot. Mortality was the result of wind damage or lightning. After the study was closed in 1961, an average of 8 overstory pines per plot (32 per acre) were removed from

Figure 1.— *Hardwood sprouts were very prevalent on this plot in July 1960 following four prescribed fires (February 1954, August 1955, August, 1957 and February 1960).*

Table 1—*Average conditions during prescribed burns*

Date of burn	Precipitation		Relative humidity	Air temperature	Fuel moisture[1]	Wind		Time of day	Type of burn
	Days since last	Amount				Velocity	Direction		
	number	*inches*	*percent*	*°F*	*percent*	*miles/hour*		*CST*	
Nov. 13, 1942	3	0.1	22	78	9	3	NW	3pm till out	backfire + headfire
Feb. 10, 1954	10	2.4	27	81	4	6-10	SW	1-3pm	backfire
Aug. 25, 1955	16	0.6	50	94	7	3-4	SW	1-2:30pm	headfire
Aug. 29, 1957	17	0.2	56	93	7	2-3	N	1-3pm	headfire
Feb. 11, 1960	5	1.3	45	55	6	1-2	N	1-3pm	backfire
Late summer 1967[2]	dry	dry	40+	90+	low	light	variable	afternoon	headfire
Feb. 29, 1980	18	2.2	55	50	14	1	W	2-4pm	backfire

[1]Determined from fuel-moisture sticks.

[2]Burned for demonstration purposes, no historical records available on exact date. Subjective information based on recollection of field personnel.

Figure 2.— *By May 1956, hardwoods had been effectively controlled on this plot (foreground) by two herbicide applications (May 1954 and June 1955).*

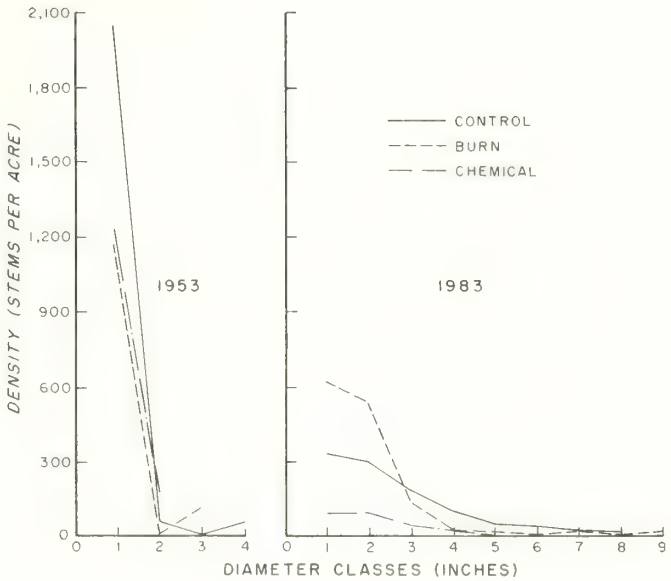

Figure 3.— *Diameter distribution of hardwoods ≥1 inch dbh in 1953 (before treatment) and 1983 (23 years after treatments ended).*

the hardwood control study area during harvest operations, which included a 1963 improvement cut over the entire 40-acre compartment.

Measurements and Data Analysis

Numbered metal tags were placed on all overstory pines on the study plots in 1953 at 4.5 feet above ground (dbh). Diameters were measured to the nearest 0.1 inch at the tagged point on each tree annually in the dormant season from 1954 through 1960. Hardwoods were inventoried by species groups in 1953 prior to treatment using 1-inch dbh classes on 9 systematically spaced milacres within each ¼-acre plot. Hardwood reinvasion data were not taken on study plots during the years that the burn and chemical treatments were being applied.

In the summer of 1983, dbh measurements were taken to the nearest 0.1 inch on all surviving tagged pines. Diameters at 4.5 feet were taken by 1-inch classes on all untagged pines and all hardwoods within each ¼-acre plot. Twelve systematically spaced milacres were used per ¼-acre plot for stem counts of woody species less than 1 inch dbh and for ocular estimation of percent herbaceous ground cover. Species identification was according to Little (1979).

All merchantable volumes were calculated from the same local volume table using dbh measurements. That table was based on a minimum upper diameter of 7.5 inches inside bark for board-foot volume in trees ≥10 inches dbh, and 3.5 inches inside bark for cubic-foot volume in trees ≥4 inches dbh. Volume production was determined as follows:

residual volume + cut volume - initial volume = volume production.

Analysis of variance for a randomized block design and Duncan's Multiple Range Test were used to test differences among treatment means for pine growth and hardwood competition at the 0.10 level of significance. Percent herbaceous ground cover was compared using the arcsin transformation.

RESULTS

Hardwood Reinvasion And Herbaceous Vegetation

In 1953, prior to treatments, hardwood density averaged over 18,000 stems per acre <1 inch dbh and over 1,600 stems per acre ≥1 inch dbh (table 2). In 1983, 23 years after treatments ended, hardwood density for stems ≥1 inch dbh was significantly higher on burn plots than on chemical plots, with most stems in the 1- and 2-inch dbh classes (fig. 3). For stems <1 inch dbh, there were no significant differences in mean density among treatments in 1983 (table 2). The prescribed fire in 1980 for fuel hazard reduction probably had an equalizing effect on low-ground hardwood competition across all treatments. Even so, in 1983 the burn plots averaged nearly 10,000 more hardwood stems <1 inch dbh per acre than did control or chemical plots. Understory species <1 inch dbh are listed in table 3.

More species were inventoried on burn plots than on either chemical or control plots, with chemical and control plots being almost equal in number of species.

Seven prescribed burns did little to reduce the hardwood basal area for any length of time. Although the controls, which had been undisturbed except for the 1980 prescribed fire, had more hardwood basal area per acre in 1983, burn plots were rapidly catching up when compared to chemically treated plots (table 2).

The relationship of prescribed fires to resprouting from hardwood rootstock is illustrated in figure 1. Sweetgum is a vigorous sprouter following prescribed fires (Brender and Cooper 1968), a fact that is consistent with findings in this study. In 1953, the density of sweetgum and blackgum stems was significantly less on plots assigned the burn treatment compared to the density on control or chemical plots (fig. 4). In 1983, the reverse was true; burn plots had significantly more sweetgum and blackgum stems

Table 2—*Hardwood status on study plots in 1953 (before treatment) and 1983 (23 years after treatments ended)*

Year and treatment	Density per acre		Mean dbh[1]	Basal area per acre
	Stems < 1 inch dbh	Stems ≥ 1 inch dbh		
	number		*inches*	*square feet*
1953				
Control	20,834a[2]	2,167a	1.11a	17.36a
Burn	15,334a	1,278a	1.18a	11.88a
Chemical	19,001a	1,389a	1.19a	10.36a
1983				
Control	18,082a	940ab	2.46a	35.79a
Burn	28,333a	1,302b	1.71a	26.67b
Chemical	16,958a	232a	1.89a	5.71c

[1]Stems ≥ 1 inch dbh.
[2]Within-year column means followed by the same letter are not significantly different at the 10-percent level.

Table 3—*Density of hardwood stems <1 inch dbh, by species and treatment, in 1983*

Species	Treatment		
	Control	Burn	Chemical
	stems per acre		
American beautyberry, *Callicarpa americana* L.	1,375	1,750	1,792
American holly, *Ilex opaca* Ait.	...	542	125
Black cherry, *Prunus serotina* Ehrh.	417	584	250
Blackgum, *Nyssa sylvatica* Marsh.	250	542	125
Devil's-walkingstick, *Aralia spinosa* L.	917	500	1,083
Flowering dogwood, *Cornus florida* L.	4,375	3,209	2,542
Huckleberry, *Vaccinium* L. spp.	4,250	5,750	5,917
Ironwood, *Ostrya virginiana* (Mill.) K. Koch	83	125	...
Parsley hawthorn, *Crataegus marshallii* Eggl.	41	708	125
Persimmon, *Diospyros virginiana* L.	...	83	125
Redbud, *Cercis canadensis* L.	41	41	...
Red maple, *Acer rubrum* L.	2,334	3,583	2,250
Red mulberry, *Morus rubra* L.	41	41	...
Red oak, *Quercus* L. spp.	1,542	1,875	625
Sassafras, *Sassafras albidum* (Nutt.) Nees	41	625	208
Sumac, *Rhus* L. spp.	250	208	1,083
Sweetgum, *Liquidambar styraciflua* L.	1,334	5,834	83
Sweetleaf, *Symplocos tinctoria* (L.) L'Her.	...	41	...
White oak, *Quercus* L. spp.	208	667	125
Winged elm, *Ulmus alata* Michx.	458	959	375
Wild plum, *Prunus americana* Marsh.	125	41	...
Witch-hazel, *Hamamelis virginiana* L.	...	125	125
Yaupon, *Ilex vomitoria* Ait.	...	500	...
Total	18,082	28,333	16,958

than either the control or chemical plots. The ratio of sweetgum to blackgum stems in 1983 was 8 to 1.

Oosting and Livingston (1964) surveyed an old-field loblolly pine stand 29 years after a single ground fire at age 35. By comparing results with those from an unburned portion of the stand, they found that the number of hardwoods in the understory of the ground fire area was double and the basal area quadruple that of the unburned area.

It is well known that prescribed fires during any season of the year will temporarily reduce the size of hardwoods by topkill, especially those <2 inches in groundline diameter. If a reduction in number of hardwood stems is desired, then repeat burns during the growing season are necessary (Harrington and Stephenson 1955, Lotti 1956, Ferguson 1957, Brender and Cooper 1968, Grano 1970b). Nevertheless, Ferguson (1961) found that, in terms of complete kill, sweetgum showed no significant relationship with season of burn.

Ocular estimates of herbaceous vegetation ground cover were significantly higher on chemical plots (76 percent) than on burn (36 percent) or control plots (15 percent) in 1983. Control plots were almost devoid of herbaceous species because of shading by overstory pines and midstory hardwoods. Similar findings have been reported in loblolly pine plantations (Blair and Feduccia 1977). Although burn plots had significantly more herbaceous ground cover than controls, the high density of hardwood sprouts that developed following the prescribed fires apparently provided sufficient shading to reduce herbaceous cover to less than half of that found on chemical plots.

Predominant herbaceous species included: Alabama supplejack, *Berchemia scandens* (Hill) K. Koch; blackberry, *Rubus* spp.; bracken fern, *Pteridium aquilinum* (L.) Kuhn; grape, *Vitis* spp.; greenbrier, *Smilax* spp.; Japanese honeysuckle, *Lonicera japonica* Thunb.; peppervine, *Ampelopsis arborea* (L.) Koehne; poison ivy, *Toxiondendron radicans* (L.) Kuntze; plus grasses and weeds not identified by species.

Pine Regeneration

When plots were thinned in 1954 prior to hardwood control, residual pine basal area ranged from 75 to 80 square feet per acre. The purpose of thinning was to increase the diameter growth of the overstory pine component, not to initiate the establishment of natural pine regeneration. Yet, the type of hardwood control treatment, or lack of treatment on control plots, had a measurable impact on pine regeneration even with high basal area stocking in the overstory.

Shading by overstory pines and midstory hardwoods on control plots precluded the establishment of pine regeneration. The combination of frequent fires and vigorous resprouting of hardwood competition resulted in a lack of pine regeneration through 1980 on burn plots as well. Only on chemically treated plots did pine naturally regenerate during or following the study, based on the 1983 inventory (fig. 5).

After the 1980 prescribed fire, additional pine regeneration became established from natural seedfall on all plots. Density of those seedlings, all <1 foot tall in 1983, averaged higher on burn plots (542 per acre) than on control or chemical plots (each had 125 per acre). Since overstory basal areas of more than 100 square feet per acre are not conducive to development of pine regeneration in the understory, it is unlikely that these intolerant pine seedlings will survive unless they are released from overstory pine and hardwood competition.

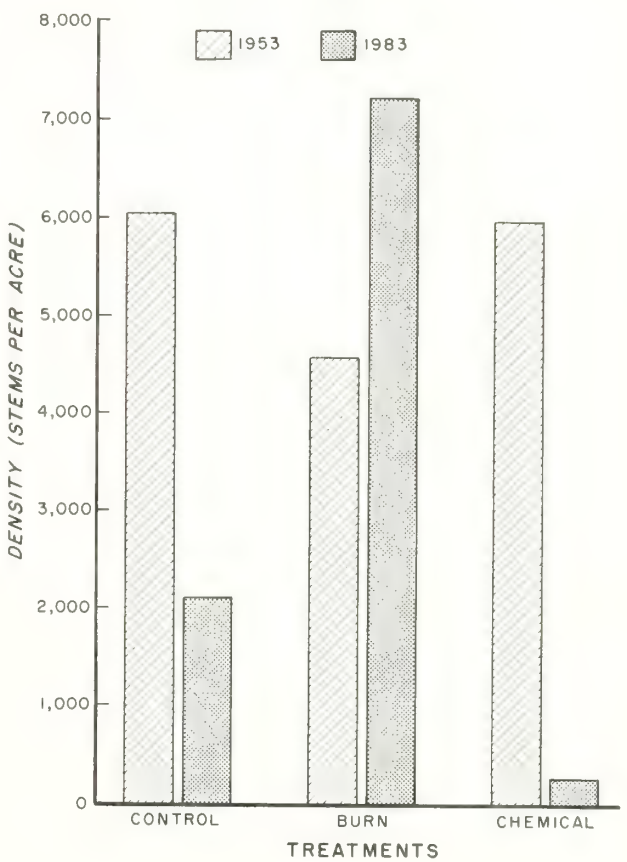

Figure 4.— *Density of sweetgum plus blackgum stems in 1953 (before treatment) and 1983 (23 years after treatments ended).*

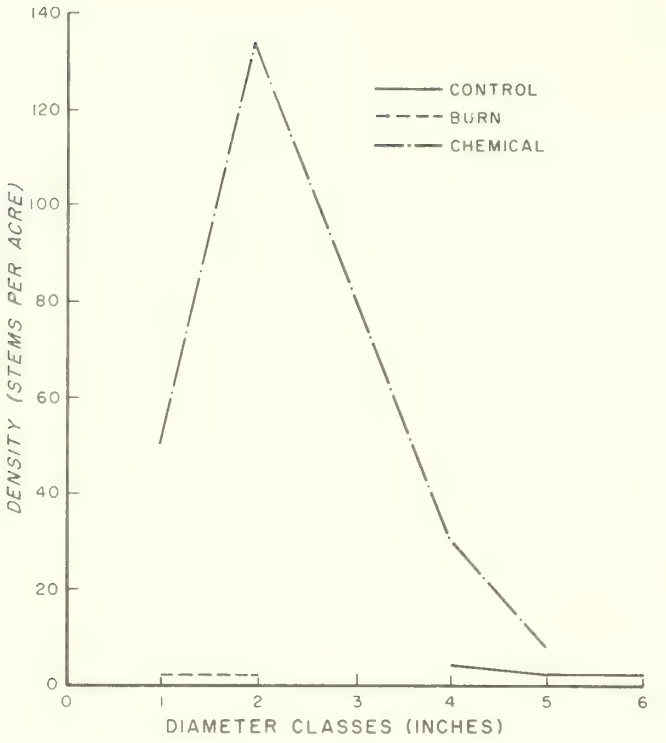

Figure 5.— *Diameter distribution in 1983 for pines ≥1 inch dbh, established during hardwood control.*

Overstory Pine Growth

While the hardwood control treatments were being maintained from 1954 through 1960, volume growth of overstory pines was extremely erratic. Over the 7-year period, chemically treated plots ranked first, control plots second, and burn plots last; but statistically significant differences were never achieved (table 4).

The 1963 improvement cut over the entire 40-acre compartment, and salvage cuts on burn plots, following the 1967 prescribed fire, resulted in unequal overstory pine densities among treatments. Volume growth was therefore confounded by differing basal area regimes between 1961 and 1983. Because of those differences, standing pine volumes in 1983 were significantly greater on control (3,997 ft^3/ac) and chemically treated plots (3,796 ft^3/ac) compared to burn plots (3,202 ft^3/ac). Consequently, a volume to basal area ratio (Bruce and Schumacher 1950) procedure was used to adjust volume production, with the assumption that the ratios were the result of treatment but that basal areas were not. With that adjustment, cubic-foot and board-foot growth per acre generally averaged higher on treated plots compared to controls both during and following hardwood control, but mean differences between treatments were statistically nonsignificant. Even without adjustment for basal area differences, long-term volume production from 1961 through 1983 was non-significant between treatment means (table 4), and averaged about 511 fbm/acre•year (75 ft^3/acre•year) across all treatments. Although there was a temporary reduction in the hardwood component from chemical or burn treatments for 7 years, posttreatment reinvasion by hardwoods and establishment of pine regeneration in the understory probably negated any long-term growth gains for overstory pines in this study.

DISCUSSION AND CONCLUSIONS

Forest managers should consider the long-term consequences of alternative silvicultural practices. Chemical treatments were more effective than prescribed burning for reducing hardwood density while this study was in progress, and that reduction was still evident 23 years after treatments ended. Although hardwoods can be top-killed by prescribed fires during winter months, rootstock tends to resprout unless prescribed burning is done during the growing season at frequent intervals. Prescribed burning may provide short-term control of hardwood competition on pine sites at relatively low cost, but cessation of burning for long periods of time may result in a more complex hardwood component than existed prior to treatment.

With appropriate site conditions, pine seedling stands can become established beneath overstory stands of loblolly/shortleaf pine. The occurrence of such regeneration in the understory can be a potential asset to landowners if establishment occurs prior to planned reproduction cuts and if pine growth is the objective of management. Chemically treated plots, unlike burn and control plots, had sapling-size pine regeneration in 1983 that could replace overstory pines as the latter are harvested, thereby shortening the length of future harvest cycles.

Long-term growth gains for overstory pines were apparently not improved by hardwood control in this study. Reasons for lack of any clear pine-growth response to hardwood control are probably related to factors such as stand age, hardwood reinvasion, and rainfall patterns.

Wahlenberg (1960) reported that the rate of cubic volume growth for loblolly pine culminates at about 40 years. When the hardwood control treatments were initiated in the present study, overstory pines were already 50 years old, so that the age for maximum growth accretion was past.

Table 4—*Status of surviving pines from 1954 through 1983, 23 years after treatments ended*

Variable	Year (s)	Treatments		
		Control	Burn	Chemical
Pine trees per acre			*number*	
	1954	112a[1]	96a	96a
	1960	110a	96b	94b
	1983	82a	56c	68b
Basal area per acre			*square feet*	
	1954	76a	79a	76a
	1960	97a	98a	96a
	1983	128a	101b	120ab
Volume production per acre			*merchantable cubic feet*[2]	
	1954 through 1960	716a	622a	754a
	1961 through 1983	1,864a	1,628a	1,708a
			board feet (International ¼-inch rule)[3]	
	1954 through 1960	4,715a	3,999a	5,134a
	1961 through 1983	12,320a	11,228a	11,694a

[1]Row means followed by the same letter are not significantly different at the 0.10 level.
[2]Volume in trees ≥4 inches dbh to a 3.5-inch top, inside bark.
[3]Volume in trees ≥10 inches dbh to a 7.5-inch top, inside bark.

Moehring and Ralston (1967) found that diameter growth of 40-year-old loblolly pines in northeastern Louisiana was curtailed when soil moisture loss was rapid, especially from June through August when available soil moisture is normally depleted. It has also been shown that a hardwood understory increases the rate of soil moisture depletion and that, by midsummer, moisture levels for plots with no hardwood understory were more than 50 percent greater than for plots with the understory present (Zahner 1958). If soil moisture is replaced by rainfall during the critical mid-summer period, the effect of hardwood removal may become less important in pine growth response. That was most likely the case in this hardwood control study, because average annual accumulation of precipitation on the Experimental Forest from 1954 through 1982 for the months of June, July and August was essentially normal (< 0.1 inch above normal).

Lack of overstory pine growth response to hardwood removal in this study should not discount the potential benefits of such treatments in younger pine stands, especially in dry years. Even without growth response, periodic hardwood control in southern pine management is often warranted to improve stand accessibility for forest workers, to insure fuel hazard reduction in case of wildfires, to improve site conditions for natural pine regeneration, or to improve requirements for wildlife.

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Cain, Michael D. 1985. Long-term impact of hardwood control treatments in mature pine stands. U. S. Dep. Agric. For. Serv. Res. Pap. SO-214, 8p. South. For. Exp. Stn., New Orleans, La.

Study examines the long-term consequence of prescribed burning and herbicide applications for control of hardwood competition in a mature, even-aged, natural stand of loblolly/shortleaf pine in south Arkansas. Comparative assessments were made on hardwood reinvasion, natural pine regeneration, and overstory pine growth.

Additional keywords: *Pinus echinata*; *Pinus taeda*; competing vegetation; hardwood reinvasion; rootsprout.

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Cultural Treatments Influence Hardwood Growth and Foliar Nutrient Concentration on a Minor Stream Bottom Site

Harvey E. Kennedy, Jr.

PUBLIC DOCUMENTS

SUMMARY

Seedlings or cuttings of nine species of hardwoods were planted on a minor stream bottom (Aeric Fluvaquents) in southeast Arkansas and mowed or disked several times annually for 4 years. Disking to eliminate competition significantly increased heights and diameters of all, and survival of some, species. Soil nitrogen, organic matter, and pH were significantly lowered in disked plots than in mowed. Cultural treatments did not affect soil phosphorus, potassium, calcium, and magnesium. More water was available for tree growth where all competition from other vegetation was removed.

On disked plots, trees had significantly higher foliar nitrogen concentrations than trees on mowed plots. Cultural treatments did not affect foliar concentrations of phosphorus, potassium, calcium, and magnesium. Foliar nitrogen level for most species was below the 2.0-percent level recommended for the best growth of cottonwood and sycamore, indicating more research with other species on different sites is needed before minimal foliar nutrient concentrations are determined.

Cultural Treatments Influence Hardwood Growth and Foliar Nutrient Concentration on a Minor Stream Bottom Site

Harvey E. Kennedy, Jr.

INTRODUCTION

Most hardwoods grown in plantations are shade intolerant, and sites must be intensively managed to eliminate competition from weeds, vines, and grasses. However, quantitative data on the effects of intensity and duration of cultural treatments on soil nutrient availability and uptake, soil moisture, tree growth, and survival are lacking for plantations. Nevertheless, forest managers are practicing intensive plantation management of hardwoods due to the demand for quality logs for veneer, lumber, and specialties. The expanding use of hardwoods for pulp and fuel also adds to this increased demand. This paper reports on soil and foliar nutrient levels, soil moisture, and growth and survival of nine hardwoods as influenced by two intensities of cultural treatment: mow and disk.

METHODS

The study site occupied about 20 acres near Monticello, Arkansas. The site recently had been cleared of a natural mixed hardwood-pine stand and prepared for planting by shearing, root raking, and disking. It is in a minor stream bottom that transects pine uplands. The soil is classified Arkabutla, a member of the fine-silty, mixed, acid, thermic family of Aeric Fluvaquents. These somewhat poorly drained soils, formed in silty alluvium, have dark-brown silt loam A horizons (surface layers) and dark-brown silty clay loam upper B horizons (subsoils) underlain by light brownish-gray silt loam. Estimated site indices for bottomland hardwoods range from 95 feet at age 50 for green ash (*Fraxinus pennsylvanica* Marsh.) to 110 feet at age 30 for cottonwood (*Populus deltoides* Bartr. ex Marsh.).

A split-plot design was used. Five blocks (3 acres each) were laid out and split into two 1.5-acre plots. One of two cultural treatments, mowing or disking, was randomly assigned to each plot. Plots were then divided into nine rows (subplots), 10 feet apart and approximately 550 feet long. One of the nine hardwood species was randomly assigned to each row. Seedlings or cuttings were planted at 10-foot intervals within rows, giving a 10- by 10-foot spacing. Rows were planted perpendicular to the contour to assure that all species were planted on bottoms, slopes, and ridges typical of minor stream bottoms. A 15-foot turn row around each major plot facilitated disking and mowing.

Because of lack of space, only one control plot (no mowing or disking), approximately 100 by 1,100 feet, was installed across the south end of the study area. It was not included in any statistical analyses of the mowed and disked treatments, but was included in tables for comparison. Four rows, parallel to the mowed and disked rows, were planted in a randomized complete block design with 10 seedlings or cottonwood cuttings per species per row. Measurements in the control plot were the same as in the treatment plots. Each row was considered a replication, and statistical analyses were made to compare performance of each species within the control plot.

Plots were disked or mowed at 3- to 4-week intervals from late April through early September the first growing season, and at 4- to 6-week intervals during the same time period in years 2, 3, and 4. Treatments were applied five times the first year, four times the second year, and three times in years 3 and 4.

Species tested were cottonwood, sycamore (*Platanus occidentalis* L.), green ash, sweetgum (*Liquidambar styraciflua* L.), sweet pecan (*Carya illinoensis* (Wangenh.) K. Koch), Nuttall oak (*Quercus nuttallii* Palmer), water oak (*Q. nigra* L.), cherrybark oak (*Q. falcata* var. *pagodifolia* E11.), and yellow-poplar (*Liriodendron tulipifera* L.).

Measurements were made of surface soil moisture and moisture at 1-, 2-, 3-, and 4-foot depths on a volume basis with neutron probes. These measurements

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were made approximately every 2 weeks when climatic and soil conditions permitted. Subsurface measurements were made using aluminum access tubes. There were six tubes located in the disked plots, six in the mowed plots, and two in the control plot.

Soil organic matter (OM), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and pH levels were determined after site preparation but before cultural treatments were started, as well as at the end of each growing season. Samples from the 0- to 6-inch layer were collected at five randomly located points within a cultural treatment without regard to species. Collections were made annually in early September and composited to make one sample per plot. Annual collections were made within 2 feet of the previous year's samples. Samples were air-dried and processed to pass through a 2-mm sieve in preparation for chemical analyses.

The above-ground portion of all understory vegetation was collected every year in early September from two 2- by 2-foot areas on the control plot. Oven-dry weights and N, P, K, Ca, and Mg concentrations were determined from composite samples.

Representative foliage samples were collected annually in early September from the midcrown position of each tree in a subplot. Concentrations of N, P, K, Ca, and Mg were determined. Samples were collected at the midcrown position to maintain uniformity in sampling.

All tree foliage and understory vegetation were dried at 70°C and ground in a Wiley mill in preparation for chemical analyses. Nitrogen was determined by a standard semimacro Kjeldahl procedure; P by colorimetry with molybdenum-blue color development; and K, Ca, and Mg by atomic absorption spectrophotometry after samples had been dry ashed and taken up in dilute HCl.

Soil N was determined by a standard semimacro Kjeldahl procedure. Phosphorus was measured with a colorimeter by the Mississippi soil test method (Soil Test Work Group 1974). Concentrations of K, Ca, and Mg were determined by atomic absorption spectrophotometry after extraction in 1 N NH_4OAc. Soil pH was measured with a glass electrode in a 1:1 soil/water ratio. Oxidizable OM was determined by chromic acid oxidation and titrations with $Fe(NH_4)_2(SO_4)_2$.

Tree heights, diameters, and survival were measured annually for 4 years. Diameters were measured with calipers at the root collar each year, because some species did not reach 4.5 feet in height until the second or third growing season. Diameters at breast height were measured after the fourth growing season. Heights were measured with an aluminum measuring pole. Effects of treatments on measured variables were tested for significant differences at the 0.05 level of confidence. Comparisons among treatment means were made using Duncan's New Multiple Range Test.

RESULTS AND DISCUSSION

Tree Growth and Survival

Significant species by cultural treatment interactions occurred for tree heights; however, individual species by cultural treatment analyses showed each species was significantly taller in disked than mowed plots (fig. 1). Disking increased heights from 76 percent for yellow-poplar to 160 percent for cherrybark oak over heights of trees in mowed plots. Significant interactions also occurred for cultural treatment by years and for species by years. These are probably a reflection of inherent growth differences between species and differences in yearly rainfall or available soil moisture. Trees were as tall after 2 years in disked plots as after 4 years in mowed plots. If this growth advantage remains, then forest managers could reduce rotation age several years by disking during the first and maybe the second growing seasons. Second-year cultivation had a significant influence on cottonwood growth during the second and third growing seasons, and these benefits were still evident in tree heights and diameters after 5 years (Baker and Blackmon 1978).

Significant cultural treatment by species interaction occurred for diameters at groundline; however, individual species by cultural treatment analyses showed that trees for each species were significantly larger in disked plots than mowed (fig. 2). Disking increased diameters from 86 percent for yellow-poplar to 229 percent for cherrybark oak over diameters of trees in mowed plots. Diameters at breast height after 4 years were 55 percent to 60 percent as large as groundline diameters.

Nuttall oak, cottonwood, and sweet pecan had significantly greater survival in disked plots than in mowed. The other six species were not affected by treatment. Even though cottonwood and sweet pecan did better in disked plots, survival was unsatisfactory (43 percent). After 4 years, survival of other species in disked plots ranged from 67 percent for yellow-poplar to 96 percent for sycamore. Competition was primarily from weeds and grasses rather than from vines, which are common on many hardwood sites. Weeds and grasses slowed growth in mowed plots; this competition was not severe enough to cause mortality.

In the control plot, sycamore and sweetgum had significantly higher survival than cottonwood and sweet pecan. Other species were intermediate with no significant differences among them in survival. Green ash, sycamore, yellow-poplar, and sweetgum were larger than cottonwood and sweet pecan in terms of height and diameter growth. Oaks were intermediate with no significant differences among them. Low survival and poor growth rates of cottonwood and sweet

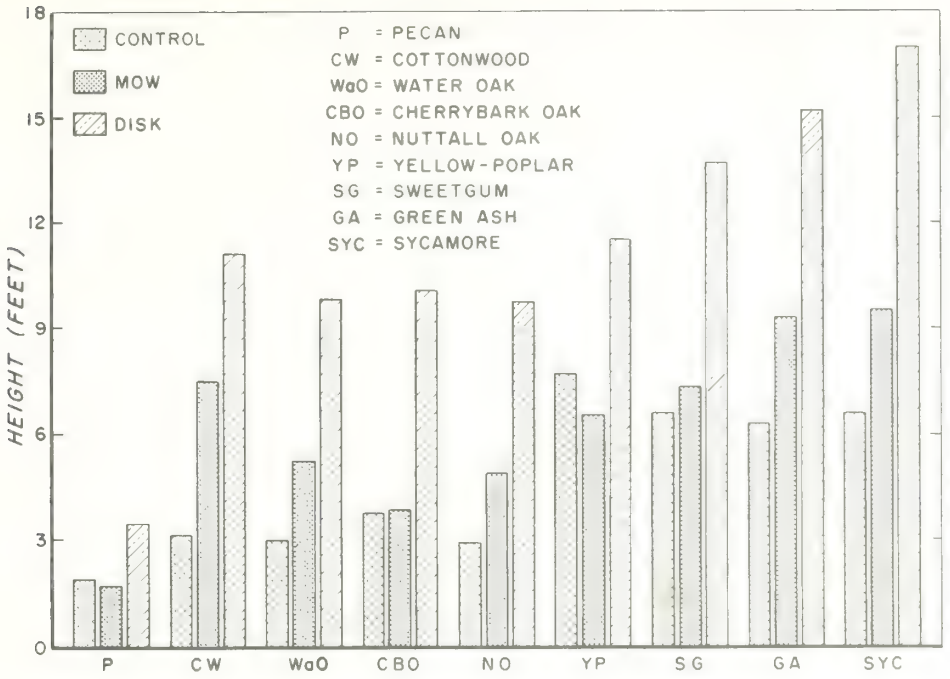

Figure 1. — *Average heights by species and cultural treatment after four growing seasons.*

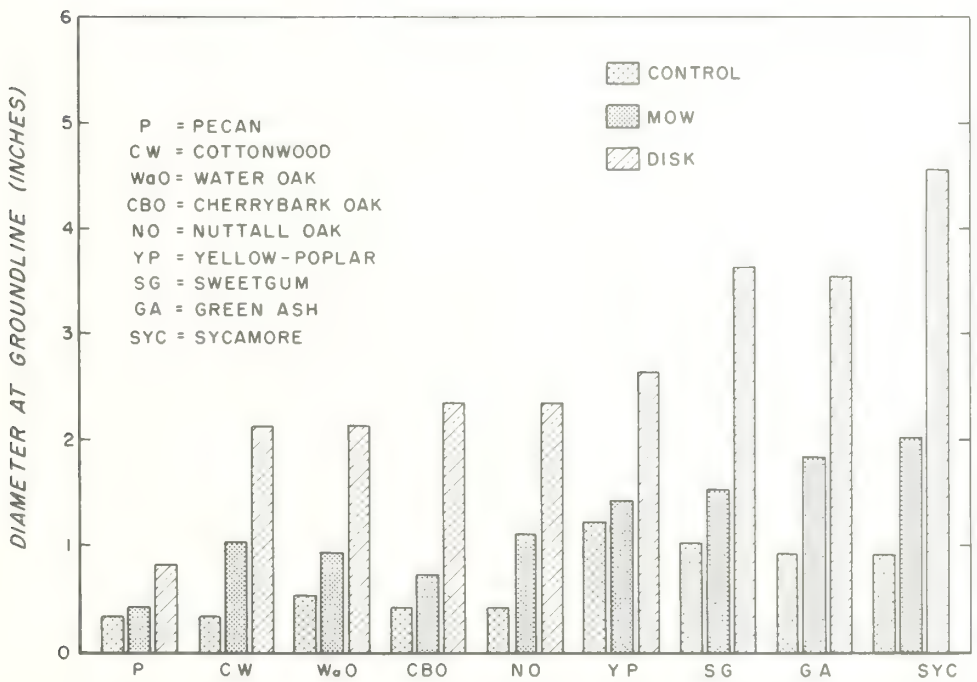

Figure 2. — *Average diameters at groundline by species and cultural treatment after four growing seasons.*

pecan indicate their unsuitability for planting on this site. Survival and growth of mowed plots and the control were very similar. Kennedy's (1981) results showed no differences in growth and survival of trees in mowed and control plots.

Trees compete strongly with weeds and grasses for moisture, nutrients, and sunlight. Annual dry-weight production of weeds and grasses in the control plot averaged 4.2 tons per acre. Nutrient concentrations of understory vegetation were: N, 0.64 percent; P, 0.07 percent; K, 0.30 percent; Ca, 0.28 percent; Mg, 0.12 percent. Better tree growth in disked plots than in mowed and control plots (figs. 1 and 2) indicated that disking eliminated the competition, resulting in more available water and nutrients for seedlings. Competition apparently still existed, whether weeds and grasses were mowed or not mowed.

Foliar Nutrients

Cultural treatments did not affect foliar concentrations of P, K, Ca, and Mg (table 1). The cultural treatment by species interaction for N was significant, so individual analyses by species were made. Green ash, water oak, sweet pecan, cottonwood, and sweetgum had higher foliar N concentrations in disked plots than mowed, but cultural treatments did not affect foliar N concentrations in cherrybark oak, sycamore, Nuttall oak, or yellow-poplar. Although cultural treatments did not significantly affect foliar concentrations of any nutrient element except N, assuming foliar weights are proportional to D^2 or D^2H, then 3 to 12 times more of each nutrient was accumulated in trees in disked plots than in mowed. Except for N, trees in the control plot had about the same nutrient concentrations as those in mowed plots.

The higher foliar N levels in trees in disked plots probably resulted from reduction in competition for the available soil N and conditions that were more favorable for the breakdown of organic matter. Researchers (Blackmon and White 1972, Carter and White 1971) have suggested a minimum nitrogen foliage level of 2 percent for best growth in several species of poplars. The 2 percent N level for good growth in sycamore has also been suggested (Norris and others 1980). Results of our research suggest that trees of several species, including sycamore, can have good growth when foliar N concentrations are below the 2 percent level.

Over the 4 years of this study, foliar P, Ca, and Mg remained relatively stable regardless of cultural treatment. Foliar N and Mg decreased with age in disked plots but was relatively stable in mowed plots. Lower N and Mg concentrations in tree foliage in disked plots probably resulted from dilution.

Soil Nutrients

Soil N, OM, and pH were significantly lower in disked plots than in mowed (table 2). Cultural treatments did not affect P, K, Ca, and Mg. Soil N dropped significantly during the first and second years. During years 3 and 4, N rebounded to the preplant level. This is probably a reflection of less leaf mass production and decomposition of OM from the former forest during the first 2 years. Disking helped incorporate OM into the soil and created conditions more favorable for decomposition than in mowed plots. During years 3 and 4, the trees probably had begun to return enough litter to the soil to offset OM decomposition.

Phosphorus, K, Ca, and Mg were also significantly altered over the 4 years (table 2). Phosphorus was

Table 1. — *Percent foliar nutrient concentrations by species and cultural treatment averaged over the first four growing seasons*

	N			P			K			Ca			Mg		
Species[1]	C[2]	M	D	C	M	D	C	M	D	C	M	D	C	M	D
GA	1.31	1.59	1.90	0.11	0.12	0.11	0.74	0.71	0.76	0.75	0.73	0.76	0.24	0.22	0.22
CBO	1.44	1.57	1.75	.09	.10	.10	.48	.48	.58	.79	.79	.70	.14	.14	.11
WaO	1.41	1.55	1.78	.08	.10	.10	.46	.57	.62	.66	.66	.65	.14	.14	.14
Syc	1.32	1.52	1.72	.10	.11	.11	.57	.62	.64	.85	.84	.75	.23	.22	.22
SG	1.45	1.48	1.61	.13	.12	.11	.48	.47	.53	.87	.91	.90	.34	.31	.28
NO	1.35	1.51	1.91	.09	.10	.10	.54	.52	.59	.54	.56	.57	.13	.12	.11
SP	1.28	1.57	2.05	.12	.11	.12	.45	.49	.51	1.87	1.29	1.47	.48	.32	.27
CW	1.33	1.77	2.32	.11	.14	.13	.64	1.03	1.13	1.43	1.17	1.06	.52	.42	.44
YP	1.55	1.68	1.69	.10	.11	.09	.45	.46	.40	1.39	1.35	1.45	.42	.36	.38
$\bar{X}$	1.38	1.58	1.86	.10	.11	.11	.53	.59	.64	.93	.92	.92	.29	.25	.24

[1] GA = green ash, CBO = cherrybark oak, WaO = water oak, Syc = sycamore, SG = sweetgum, NO = Nuttall oak, SP = sweet pecan, CW = cottonwood, YP = yellow-poplar.
[2] C = Control, M = Mow, D = Disk.

Table 2. — *Nutrient levels in the upper 6 inches of soil by cultural treatment and year*

Cultural treatment	Year[1]				
	0	1	2	3	4
	N-percent				
Control	0.084	0.077	0.059	0.081	0.101
Mow	.089	.080	.070	.088	.084
Disk	.072	.055	.052	.061	.081
X	.081a[2]	.068b	.061c	.075a	.083a
	P-ppm				
Control	5.0	6.0	4.0	5.0	5.0
Mow	7.0	6.6	5.6	4.4	2.6
Disk	8.2	6.0	3.6	3.4	3.0
X	7.6a	6.3a	4.6b	3.9b	2.8c
	K-ppm				
Control	81	58	72	64	50
Mow	92	79	89	76	57
Disk	87	77	82	74	56
X	90a	78a	85a	75a	57b
	Ca-ppm				
Control	338	375	225	300	300
Mow	503	500	299	480	247
Disk	435	397	322	360	345
X	469a	449a	310b	420a	296b
	Mg-ppm				
Control	165	150	112	135	63
Mow	197	183	163	176	83
Disk	180	179	171	167	102
X	189a	181a	167a	172a	93b
	OM-percent				
Control	1.55	1.62	1.42	1.73	2.18
Mow	1.74	1.58	1.48	1.94	1.78
Disk	1.50	0.94	1.30	1.42	1.72
X	1.62a	1.26b	1.39b	1.68a	1.75a
	pH				
Control	5.58	5.75	5.82	5.70	5.58
Mow	5.70	5.69	5.50	5.77	5.51
Disk	5.46	5.30	5.37	5.65	5.70
X	5.58a	5.50b	5.44c	5.71a	5.70a

[1] Year 0 is for nutrient levels before cultural treatments were applied; others are after each growing season.

[2] Means of mowed and disked only; means for a given element followed by the same letter are not significantly different at the 0.05 level. Control is shown for comparison only.

highest before planting and at the end of the first growing season. It was lowest after the fourth year, while years 2 and 3 were intermediate and not different from each other. Potassium and Mg levels did not change the first 3 years, but dropped significantly in year 4. Calcium levels were the same before planting and after years 1 and 3. In years 2 and 4, Ca was significantly lower than the other sample times. July and August of the fourth year were the driest months recorded during the study and probably accounted for the lower amounts of P, K, Ca, and Mg measured that year.

Disked plots were significantly lower than mowed in organic matter. This probably resulted from increased decomposition of OM after incorporation into the soil in disked plots. Organic matter was also lower in mowed plots during the first and second years than before planting and after years 3 and 4. This trend was expected because of higher decomposition rates after planting and less leaf fall in years 1 and 2 than later in the life of the plantation. The cultural treatment by year interaction was significant but did not appear as important as the main effects. The interaction was probably caused by the decline in OM in disked plots during the first growing season.

Soil pH was significantly lower in disked than mowed plots and is probably a reflection of the release of organic and inorganic acids during OM decomposition. However, the range from lowest to highest was not wide and probably there were not large enough differences to affect tree growth and survival.

Soil Moisture

Soil moisture content did not differ by cultural treatment. Soil moisture was highest at the beginning of the growing season under all cultural treatments and diminished during the growing season. Evapotranspiration from a fully stocked forest stand in the Gulf South is about one-fourth of an inch per day. Up to 50 percent of the moisture loss in a pine forest stand can be attributed to the hardwood understory (Zahner 1958). In our study, soil moisture absorbed by weeds and grasses in the mowed and control plots was not available for uptake by trees. On disked plots, this loss did not occur because weeds and grasses were destroyed and soil moisture was available for uptake by the trees. Apprently, trees in disked plots absorbed as much water as weeds and grasses in other plots, because no differences in soil mositure content among treatments were detected. Evidently as much as 50 percent more moisture could have been available for uptake by trees in disked plots than in mowed and control plots.

Soil moisture depletion varied by depth during the year. Moisture in the surface and at the 1-foot depth was lowest as the growing season progressed, followed by the 2-foot depth. At the lower depths of 3 and 4 feet, soil moisture remained relatively constant during the growing season, indicating that most roots did not extend below 2 feet, or there was sufficient water movement from lower horizons into this rooting zone to maintain moisture levels.

CONCLUSIONS

One of the major benefits of disking was control of weeds and grasses. By eliminating this competition, disking directly or indirectly increased nutrient concentrations and the amount of soil moisture available for uptake by trees, as evidenced by increased tree growth. Without good site preparation and disking, lower survival and reduced growth of planted trees can be expected.

The study site is considered relatively infertile for hardwoods, because soil nutrients are near or below what is considered to be the minimal level for good tree growth, particularly for P, K, and Ca (Davey 1976). Foliar N for most species was below the 2.0 percent level recommended for good growth in cottonwood and sycamore (Carter and White 1971, Norris and others 1980). However, 4-year growth was good for all species except cottonwood and sweet pecan (which had foliar N concentrations above 2 percent in disked plots). More research is needed with other species, including sycamore, on different sites before minimal foliar nutrient concentrations and soil nutrient levels are determined.

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Influence of cultural treatments on soil and foliar nutrient levels, soil moisture, and growth and survival of nine hardwoods was studied.

Additional keywords: Plantation, soil moisture, soil nutrients, *Fraxinus pennsylvanica, Quercus* spp.

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Pine Release in Unevenly Stocked Stands on Droughty Soils May Be Uneconomical

Richard W. Guldin

SUMMARY

A very hilly tract of loblolly pine-hardwood forest totaling 1,500 acres was direct-seeded in 1967. A 40-acre parcel within the tract was treated with 2.5 lb active ingredient per acre of 2,4,5-T in 1972. Oaks on the treated area are significantly smaller than oaks on the untreated area, but only the pines growing in stream bottoms showed a significant response to release. Droughty soils and the difficulties of uniformly sowing seed and spraying herbicides from aircraft in very hilly terrain appear to have contributed to the spotty pine response.

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INTRODUCTION

Aerial application of herbicide sprays has been quite popular because it allows large areas to be covered rapidly. When evaluating pine release options, forest managers commonly weigh two key factors—cost of the treatment and expected results. But obtaining the desired results depends not only on selecting the proper chemical for the target species and obtaining uniform application, it also depends on the condition of the stand to be released and site factors such as soil type, slope, erosion, etc. Costs are typically a function of the amount of the chemical used and the application expense. Benefits are typically a function of the stand and site interactions. Managers must evaluate both expected costs and expected benefits when planning a release program.

The purpose of this paper is to report results obtained when an unevenly stocked stand growing on a site having considerable variation was released. The release treatment was a pilot-scale operational treatment applied in 1972, following procedures that were commonly accepted at that time. The treatment typifies the kind of informal testing or trial evaluation landowners give to new management practices. The question often asked is, "Will this new treatment work for our situation?" This paper demonstrates the kinds of problems that can arise in interpreting results of such treatment trials.

STUDY AREA

In 1966, 1,500 acres of loblolly pine-mixed oak forest in south-central Tennessee were clearcut to remove pine and hardwood pulpwood. The tract, located approximately 10 miles east of the town of Savannah in Hardin County, was sheared following harvest. In late summer, a broadcast burn was attempted with poor results. The entire area was direct-seeded by helicopter in the winter of 1966–67. Flight lines for the seeding operation ran due north and south, parallel and perpendicular to the tract's exterior boundaries and bisecting the ridges and bottoms of the study area at a 45° angle. During the next 5 years, many of the sheared hardwood stumps sprouted.

The study area is a 40-acre parcel within the 1,500 acre tract. Soils in the cutover area are predominantly sandy loams and gravelly sandy loams of the Waynesboro soil series, although lesser quantities of Shubuta fine sandy loam and Silerton silt loam exist. Numerous small streams cut through the tract, generally flowing to the northwest. Because the soils are highly erodable, the streams have cut steep-sided, narrow bottoms through the area and created irregular, choppy ridges having the same general northwesterly orientation. Slopes range from 5 to 45 percent. Soils of all three series are deep, well-drained to excessively well-drained, and low in fertility and organic matter (Proffitt and others 1963). Site indices for loblolly pine are 75 to 85 feet at 50 years for all three soils, and other vegetation provides moderate to severe competition to planted pines (Proffitt and others 1963).

In June 1972, the 40-acre parcel was sprayed with 2,4,5-T in diesel oil and water. Eight gallons of spray were applied per acre, consisting of 0.625 gallon of 2,4,5-T (4 lb active ingredient per gallon), 1 gallon of diesel oil, and 6.375 gallons of water. The treated area was 10 chains wide and 40 chains long with the long axis on a bearing of N34°E (magnetic). This particular parcel was selected for treatment because it was representative of the entire 1,500 acres, and the existence of the roads about 40 chains apart simplified the job of flagging flight paths. The flight paths followed the long axis of the block, cutting roughly perpendicularly across the ridges and bottoms. No other silvicultural treatments have been applied to the area since then.

DATA

In April 1984, the treated 40 acres and an adjacent untreated area were sampled to measure tree densities per acre, diameters, and heights and to recover

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increment cores from the pines. The pines were just beginning their first flush of growth for the year, so measurements reflect the stand's status at the end of the 1983 growing season—11 years after spraying. The reported growth results cover the first decade after treatment (1972–82).

A series of 17 plots was measured off inside the treated area at 2-chain intervals on a line following the long axis of the sprayed parcel. Although the corners of the treated area were not monumented, the northeastern corner was fixed by a road junction, the southern border by a woods road, and bearings of the borders had been recorded. Sufficiently large buffers were allowed to assure that all plots were within the area sprayed.

A series of 18 plots was measured off outside the treated area, also at 2-chain intervals. This line of plots was established 8 chains from the northwest corner of the treated parcel and angled 2 degrees away from the border of the treated area to allow for possible deviations of the helicopter flight line in the irregular terrain. This untreated area was "upwind" according to prevailing air currents and had the same types of soils and topography as the treated area. The untreated area was also seeded on the same flight paths as the treated area.

On each plot, site information was recorded, and a BAF 10 factor prism was used to identify the trees to be tallied. Each tree was measured to determine d.b.h. and total height. Each pine was bored at breast height to obtain an increment core for subsequent analysis of radial growth over time (table 1).

Table 1.—*Stand conditions in 1983*

Measurement	Treated area	Untreated area
Number of trees		
Loblolly pine	102	96
Mixed oaks	58	71
Other hardwoods	4	10
Mean d.b.h. (inches)		
Loblolly pine	6.2	6.1
Mixed oaks	3.9	5.2
Other hardwoods	5.0	4.4
Mean total height (feet)		
Loblolly pine	39.5	41.1
Mixed oak	33.6	41.6
Other hardwoods	40.2	39.7
Mean stand basal area (square feet/acre)		
Loblolly pine	63.8	53.3
Mixed oaks	36.2	39.4
Other hardwoods	2.5	5.6
Total	102.5	98.3

RESULTS

As a result of the irregular topography of the area, the plots were split into two categories, ridges and stream bottoms, to determine if plot location affected growth response. For purposes of categorization, stream bottoms included areas where plot centers were within 1 chain of a flowing stream or where there was evidence of an intermittant stream, such as a drainage channel. This definition includes the bottoms themselves, which tended to be relatively narrow, plus the lower portions of the slopes bordering the bottoms. Ridges included flat areas on tops of ridges, plus the upper slopes where drainage occurs by overland flow rather than through gullies. One plot was omitted from the analysis because it obviously fell in an area between flight paths (a "skip") of the direct-seeding operation. Fifty percent of the treated plots were in stream bottoms, compared to 40 percent of the untreated plots.

Duncan's multiple range test (Duncan 1955, Kramer 1956) was used to evaluate differences in mean pine height, mean pine d.b.h., and mean pine periodic diameter increment for the decade after release (table 2). Pine heights did not differ significantly (0.05 levels), either between ridges and bottoms or between treated and untreated areas. This result verifies that site index is the same across the three soil types encountered, as indicated by Proffitt and others (1963).

Mean pine d.b.h. differed both by location and treatment. On the treated area, mean pine d.b.h. was 0.9 inch greater in the bottom than on the ridges (significant at the 0.05 level) and 1.1 inches greater in treated than in untreated bottoms (significant at the 0.05 level). Pine d.b.h. differences between ridges and bottoms in the untreated area were insignificant. Further, the mean pine d.b.h. on the ridge did not differ between treated and untreated areas.

The average periodic pine diameter increment for the 10 years after release (1972–82) was calculated from ring widths of the increment cores. Results showed that the largest periodic increment occurred in treated bottoms. It was 0.64 inch larger than the periodic increment of pines in the untreated bottoms (significant at the 0.05 level), showing evidence of a pine growth response to the release treatment in this topographic location. The periodic increment of pines in the treated bottoms was also 0.64 inch larger than the periodic increments added to pines growing on the ridges of the treated area (significant at the 0.05 level). The periodic increment of the pines on the treated ridges was not significantly different from period increments of pines growing at either location in the untreated area.

Table 2.—*Pine responses between ridges versus bottoms and treated versus untreated areas during 1972–82 for comparison*[1]

	Pine heights		Pine d.b.h.		Average periodic diameter increment	
	Treated	Untreated	Treated	Untreated	Treated	Untreated
	feet		*inches*			
Ridges	39.0 a	41.0 a	5.86 b	6.53 ab	3.62 b	3.92 ab
Bottoms	40.7 a	42.6 a	6.75 a	5.64 b	4.26 a	3.62 b

[1]Entries followed by the same letter are not significantly different at the 0.05 level, according to Duncan's multiple range test.

The growth increments for the treated and untreated bottoms, where significant differences existed, were divided into two 5-year increments. T-tests revealed that a growth response was still occurring the second 5 years after release. This finding supports a similar finding by Guldin (1984) that studies should be monitored for a full decade after treatment to measure the full diameter growth response to release.

Significant differences (0.01 level) were found in mean oak d.b.h. and mean oak height between treated and untreated areas. No significant differences existed between ridge and stream bottom locations within either treated or untreated areas. Non-oak hardwoods accounted for less than 10 percent of all hardwoods—too few for meaningful analysis.

Mean hardwood basal area in the treated bottoms was less than half that of the untreated bottoms—27.5 versus 57.1 square feet per acre, respectively (significant at the 0.05 level). Mean hardwood basal area on the ridges was not significantly different between treated and untreated areas, nor significantly different from that on untreated bottoms.

Mean pine basal area was 10.4 square feet higher (20 percent) on the treated area than on the untreated area. However, when tested statistically, the great variability in pine basal area per plot (standard deviations of 31 and 38 square feet per acre, respectively) rendered insignificant the difference in mean pine basal area per acre.

It was evident on both the treated and untreated areas that the shearing and burning site preparation treatments failed to prevent hardwood regeneration by sprouting. Of the 143 hardwoods tallied on the plots, 67 percent were obviously stump sprouts. Between treated and untreated areas, neither the number of sprouting stumps (1.06 versus 1.00) nor the number of sprouts per stump (2.53 versus 2.63) substantially varied. The plots in the untreated area averaged 18 square feet of basal area per acre of hardwoods that were not obviously of sprout origin, compared to only 10 square feet per acre for treated plots. Because oak diameters differed between treated and untreated areas, the difference in basal area implies differences in both the number and size of hardwoods. The untreated area averaged more non-sprout hardwoods per acre (115 versus 75) of larger average size (6.4 inches versus 4.4 inches) than the treated area.

DISCUSSION

The pattern of pine diameter response in this study suggests that soil moisture was the determining factor as to whether or not a release response occurred. The treatment stunted oak growth both on ridges and in bottoms, as evidenced by the significant difference in mean oak d.b.h.'s. But pines on the ridges were not able to take advantage of the treatment. A major contributing factor was probably the lack of sufficient soil moisture for optimum pine growth. The ridge soils are excessively well-drained, so any rainfall percolates rapidly down below the pine rooting zone. In the bottoms where soil moisture is more plentiful, the pine response was significantly higher for the treated area than for the untreated area.

Moisture probably also influenced differences in oak basal area. Miller and Star (1963), Darrow (1957), and Elwell and others (1956) all reported that adequate available soil moisture at time of spraying is essential for effective control of oaks with 2,4,5-T. In the droughty, excessively well-drained soils of the study area, there may not have been enough soil moisture to permit the oaks to completely translocate the 2,4,5-T from foliage throughout the tree and kill the oak root system. In the bottoms of the treated area, more water would have been available. The fact that oak basal area there is half the basal area in either the untreated bottoms or the treated slopes suggests that soil moisture may have been a limiting factor in reducing the effectiveness of the treatment on oaks located on the drier ridges.

The variation in pine basal area arose, in part, from the quality of the direct-seeding operation used to establish the stand. Uniform distribution of seeds and spray by helicopter depends on the pilot's skill in maintaining a constant altitude over the ground

traversed. The topography of the study site made it virtually impossible to maintain constant altitude over all points on the ground. Aerial photographs taken in March 1982 clearly reveal the uneven pine stocking of the stand that was established. Pines tend to be thicker on the ridges (where the aircraft altitude above ground was least) and more widely scattered on lower slopes and valley bottoms (where aircraft altitude above ground was greatest). Flight paths are distinct and skips between paths are common. The study data support this tendency for pines to be thicker on the ridges, but the large standard deviations for pine basal area preclude statistical confirmation of the trend.

Because pines are denser on the ridges, more of the pine competition on ridges likely came from other pines. Thus, intraspecies competition among pines, which was not affected by the herbicide application, may have been relatively more important on the ridges than the interspecies competition between pines and oaks. In the bottoms where pine stocking was relatively lower because of the greater aircraft-to-ground distance when seeding, interspecies competition with oaks, other hardwoods, and herbaceous vegetation was more important.

The topography probably also affected herbicide distribution—placing more herbicide on ridges where it was needed least and less in the bottoms where it was needed the most. The ridgetops that were more densely stocked with pine, which suffered from intraspecies competition, received more spray per unit area than the lower slopes and valley bottoms because the helicopter pilot could not satisfactorily adjust the altitude of the aircraft for every valley or draw.

This is the second study of long-term pine response to release that failed to find a significant height growth response (cf. Guldin 1984). This finding is of particular importance when one reviews much of the current herbicide efficacy research, which typically uses height growth as an important measure of pine response (cf. Fitzgerald and Griswold 1984, Gnegy and Lichy 1984). Height increment may be a useful short-term indicator of a possible response, but as trees grow over time, the significance of the height increment diminishes. What was once a significant height difference when the trees were less than 15 feet tall becomes insignificant 10 or more years after spraying. Even if statistically different, a height difference of 4 to 6 feet at age 10 or less may not be of any economic consequence on a per-acre basis at harvest when valued as pulpwood. Because significant diameter responses have been found in this study and in Guldin (1984), researchers should seek ways to monitor radial growth differences as early in a tree's life as possible. For trees less than 4.5 feet tall, Michael (1984) suggests diameter at 3 inches above ground.

The lack of a long-term height growth increment also has an impact on projecting, from short-term studies, the growth and yield increases due to release. Previously, long-term growth and yield increases have been projected by comparing the differences in yields, using volumes obtained from stand tables that are a function of age and site index (height). The mean height of saplings in the control group at a given age was used to project site index in the absence of treatment, and the taller height of the released saplings at the given age was used to project a higher site index with treatment. The two site indexes were then used to read volumes at rotation age from a yield table. The difference in yields, induced by differences in site index, was assumed to be the yield increase due to release. But if there is no long-term difference in heights, as found in this study and in Guldin (1984), this method of estimating volume differences from differences in site index, based on a short-term height increment, may not give verifiable results. It appears that adjusting the diameter distribution of an untreated stand to reflect the diameter increment response to release and then using the same site index to project two different stand tables would be a better, albeit more mathematically complex, approach.

A stand table constructed from the pine data reveals that the treated area does have an additional cord of pulpwood and an additional 1.1 cords of chip-n-saw stumpage per acre 11 years after release (table 3). But because the pine basal areas are not significantly different, the pine volumes are not statistically different either. Whether the treated area will ever produce a substantially greater return on the release investment questionable.

CONCLUSION

Differences in response to release were found that depended on whether or not the pines were growing on ridges or in bottoms. Although topographic location had no effect on height growth, it did affect diameter growth response. The most likely reason for response differences by location is that soil moisture is more prevalent in the bottoms. The well-drained ridge soils may have lacked sufficient moisture at time of spraying to obtain satisfactory translocation of the herbicide in the oaks. Insufficient water in the ridge soils may also have prevented the pines from taking advantage of the growing space that did become available to respond to the treatment with increased

Table 3.—*Pine diameter, height, and volume distributions per acre in 1983*

D.b.h. class	Treated stand			Untreated stand		
	Stems/acre	Height	Volume[1]	Stems/acre	Height	Volume
inches	*number*	*feet*	*cords*	*number*	*feet*	*cords*
2	29	29	.	51	34	. .
3	64	31	. .	56	36	. .
4	64	34	0.7	51	37	0.6
5	92	36	2.0	86	39	1.8
6	70	39	2.3	65	41	2.2
7	40	41	2.1	29	43	1.5
8	29	44	2.2	18	44	1.3
9	13	46	1.3	11	46	1.1
10	2	49	.3	1	48	.1
11	1	51	.2	1	50	.2
12	. .	. .	. .	1	51	.2
Total	404		11.1	370		9.0

[1]From Table 3 of USDA (1929; p. 21) .

diameter growth. The best time to release stands on such droughty soils is immediately after a prolonged period of heavy rain early in the spring when the hardwood leaves are fully developed.

When these growth results are combined with the uneven stocking obtained from direct-seeding by aircraft in the very hilly terrain, it becomes impossible to discern a significant difference in present worth value between the treated 40 acres and the surrounding untreated area. In this study, stand and site factors were extremely important elements in evaluating the economic feasibility of release using aerially applied herbicide sprays.

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A very hilly tract of 40 acres, direct-seeded in 1967, was sprayed with 2.5 pounds active ingredient of 2,4,5-T in 1972 to release pines from competing hardwoods. Only pines growing in stream bottoms of the treated area responded.

Additional keywords: 2,4,5-T, herbicides, growth, yield, response, direct seeding, height growth.

DISCLAIMER

Discussion of herbicides in this paper does not constitute recommendation of their use or imply that uses discussed here are registered. If herbicides are handled, applied, or disposed of improperly, they can harm humans, domestic animals, desirable plants, pollinating insects, fish, and other wildlife as well as contaminate water supplies. Use herbicides only when needed and handle them with care. Follow the directions and heed all precautions on the container label.

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Impact of Insects on Growth and Development of Young Cottonwood Plantations

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SUMMARY

Five-year study results of insect impact on early growth and tree form in six young cottonwood plantations are reported. Height, diameter growth, and tree form scored significantly better in plots protected from insects. Five-year-old trees averaged approximately 4 feet taller, 0.5 in. larger in diameter, and scored better in tree form in protected plots than in unprotected plots. In the timeframe of the study, insect populations occurred only lightly, and their impacts on trees were also light. However, most impact differences between protected and unprotected plots still were statistically significant at these low levels of infestation. Cottonwood twig borer, cottonwood leaf beetle, poplar tent maker, cottonwood borer, and aphids were the major plantation insect pests encountered.

Impact of Insects on Growth and Development of Young Cottonwood Plantations

J. D. Solomon

INTRODUCTION

Eastern cottonwood, *Populus deltoides* Bartr., is a fast-growing plantation species that has generated considerable interest in its intensive culture over the past 20 years (McKnight 1970). An estimated 40,000 to 50,000 acres of commercial plantations have been planted in the lower Mississippi River Valley (Krinard and Johnson 1980). A major problem of such monocultural plantings, however, is vulnerability to a large number of pests (Oliveria and Abrahamson 1976). Major insect pests of cottonwood plantations include the cottonwood leaf beetle, *Chrysomela scripta* F., poplar tent maker, *Clostera inclusa* (Hubner), cottonwood twig borer, *Gypsonoma haimbachiana* Kft., cottonwood clearwing borer, *Paranthrene dollii* (Neum.), cottonwood borer, *Plectrodera scalator* (Fab.), aphids, *Chaitophorus* spp., leafhoppers, and mites (Morris et al. 1975). Studies in cottonwood nurseries indicate that insects can significantly reduce height growth and the number of cuttings produced (Solomon et al. 1976, Abrahamson et al. 1977). Although general opinion is that heavy insect infestations can also adversely affect young cottonwood plantations, no formal studies of insect impact had been made prior to this study. To fill the void, this study was initiated to evaluate insect impact upon growth and development of young commercial cottonwood plantations. The results of this impact study are reported here to help managers make practical decisions in the management of cottonwood insect pests.

METHODS AND MATERIALS

Impact studies were initiated in first-year commercial cottonwood plantations owned by Crown Zellerbach Corp. at Fitler, Miss.; Anderson-Tully Co. at Eagle Lake, Miss.; and U.S. Gypsum Co. at Lake Providence, La. Study sites were planted with cuttings at a spacing of 12 × 12 ft. at Fitler and 10 × 14 ft. at Eagle Lake. At the Lake Providence sites, within row spacing was 10 ft., and spacing between rows was alternately 10 ft. and 18 ft. with the 18-ft. space interplanted to soybeans during the first two growing seasons. Plantations at Fitler and Eagle Lake were established with a randon mixture of five Stoneville select clones (clones 66, 67, 74, 92, 109). Those at Lake Providence were planted to clone 66 in 1975 and clone 67 in 1976.

The impact or loss caused by insects was determined by measuring selected variables in protected and unprotected plots and comparing differences over 5 years of growth. A plot consisted of 6 rows of 9 trees for a total of 54 trees, except at Eagle Lake where plots were smaller (4 rows of 8 trees for a total of 32 trees) because part of the plantation was lost to high spring floodwater. Plots (protected and unprotected) were replicated 10 times in a randomized complete block design in each plantation. Sets of plots were installed in 1975 and 1976 at each of the three locations.

Protected plots were treated with 20 lbs. of 10 percent granular Furadan (carbofuran 2 lbs. a.i. per acre) applied to the root zone with a subsoil applicator (Abrahamson et al. 1973, Oliveria and Solomon 1977, Solomon and Oliveria 1977) annually in June of the first 3 years for insect control. In addition, Sevin (carbaryl 1 lb. a.i. per acre) and/or Dursban (chlorpyrifos 0.25 a.i. per acre) were applied by ground equipment in a few cases to insure insect control in the protected plots before the systemic insecticide, Furadan, was applied.

Ten trees (5 best trees from each of the 2 inner rows) were selected from each plot and marked for observation and measurement over the 5-year period. Any measurable defoliation was assessed as percent defoliation during a growing season. The number of cotton-

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This paper reports research involving pesticides. It does not constitute recommendations for their use, nor does it imply registration under FIFRA as amended. Use all pesticides selectively and carefully, following recommended practices. Read and follow all label directions.

wood twig borer attacks per 18-inch terminal was counted at the end of the first growing season only.

Height, diameter at breast height (d.b.h.), and tree form rating were taken after the leaves had dropped at the end of each growing season (fig. 1). Tree form, which takes into account crooks, forks, and abnormally heavy branches, was scored to evaluate the adverse effects of insects upon form development (figs. 1–4). The following scoring system (based on a score of 1–9 with 1 being best and 9 poorest) was developed to rate tree form:

1. Trunk straight or nearly so, crooks deviating no more than 4 inches from straight line, no heavy branches, no forks.
3. Trunk with crooks deviating 4–8 inches from straight line, and/or moderately heavy branches, no forks.
5. Trunk with crooks deviating 8–16 inches from straight line, or extremely heavy branches, or fork in upper 1/3 of trunk.
7. Trunk with two or more factors listed for no. 5.
9. Trunk with crooks deviating more than 16 inches from straight line, and/or fork in lower 2/3 of trunk.

Scores of 2, 4, 6, and 8 were used when tree form was deemed to fall between any two defined scores. Furthermore, it is assumed that these scores are approximately of interval scale, although their distribution is not necessarily normal.

An analysis of variance for a randomized complete block design was used to compare annual heights, diameters, and insect populations in each plantation, and for all plantations combined. Separate analyses were made to test for differences at the 0.05 level of significance. Friedman's nonparametric test was used to compare differences in tree form scores at the 0.05 level.

RESULTS AND DISCUSSION

Insect populations varied from year to year and among plantations. No epidemics occurred during the study period. Tree growth varied widely among the six cottonwood plantations.

Plantations 1 and 2 (Fitler)

Height growth was significantly better in protected plots than in unprotected plots during each year of the 5-year study (table 1). After the first growing season, trees in protected plots were 1.2 to 1.4 ft. taller than those in unprotected plots. Five-year-old trees in protected plots in plantations 1 and 2 averaged 47.8 and 60.4 ft., respectively, compared to 42.9 and 55.1 ft. in unprotected plots, yielding height advantages of 4.9 and 5.3 ft. at the end of the 5-year study period. Diameter growth was significantly greater in protected plots 4 of 5 years in both plantations and ranged from 0.09 to 0.63 in. (table 1). Tree form in terms of bole straightness, crooks, forks, and heavy branches was significantly better during 4 of the 5 years in plantation 1, and 3 of the 5 years in plantation 2 (table 1).

Insect populations in the Fitler plantations varied from year to year but were mostly light throughout the 5-year study (table 2). Cottonwood twig borer attacks counted during fall of the first growing season were significantly higher in unprotected plots than in protected plots at plantation 1, but were considered light at both plantations—averaging less than 3 attacks per 18-in. terminal even in unprotected plots. Protected plots in both plantations were sprayed twice in 1977, once with Dursban and once with Sevin, during early season before the annual carbofuran application to insure control of cottonwood leaf beetle populations in protected plots. However, defoliation from leaf beetles never exceeded 30 percent even in the unprotected plots and caused little terminal damage. A moderately heavy late season aphid infestation in 1976 was controlled initially by the June applications of carbofuran, but by late fall trees in both protected and unprotected plots sustained moderate terminal injury (fig. 2). Light leafhopper populations were significantly higher in unprotected plots than in protected plots during the first year of growth, and the poplar tent maker caused light defoliation (less than 20%) in study plots. Numbers of both pests were too low to cause serious injury to plot trees.

Plantations 3 and 4 (Eagle Lake)

Differences in height growth between protected and unprotected plots were significant during each of the 5 years in plantation 3 and during 3 of the 5 years in plantation 4 (table 3). At age 5, trees in protected plots at plantation 3 averaged 62.6 ft. tall compared to 58.9 ft. for unprotected plots, an increased height growth of 3.7 ft. At plantation 4, tree height was only 2.9 ft. greater in protected plots after 5 years. Differences in diameter growth corresponded closely with those of height growth. Diameter growth was significantly better in protected plots during each of the 5 years at plantation 3 (0.2- to 0.5-in. differences) and during 3 of the 5 years at plantation 4 (0.05- to 0.38-in. differences). Tree form was significantly better in protected plots during 2 of 5 years at both plantations 3 and 4.

Slightly smaller height growth differences between protected and unprotected plots and the Eagle Lake plantations compared to the Fitler sites may be attributed to less insect activity. Cottonwood twig borer numbers were significantly higher in unprotected plots than in protected plots at plantation 3; yet, in reality, numbers were very low in both plantations (table 2). A heavy poplar tent maker infestation occurred at Eagle Lake in 1977 and 1978. The protected

Figures 1–4.—*Insect impact in young cottonwood plantations. (1) Measurements of insect impact being taken in a commercial plantation—trees exhibit relatively good form. (2) Terminal killed back 12 inches by cottonwood twig borers and aphids. (3) Fork and heavy branches developed as result of terminal mortality. (4) A fork developed when terminal was killed during first year, but by end of second year, the right side of fork had become only a heavy branch.*

Table 1.—*Impact of insects on the first five years of growth and tree form in young cottonwood plantations at Fitler, MS*[1]

Age (Yrs)	Mean height (ft)			Mean d.b.h. (in)			Mean tree form score (rank)[2]		
	Protected	Unprotected	Diff.	Protected	Unprotected	Diff.	Protected	Unprotected	Difference
Plantation no. 1 planted in 1975									
1	9.3	8.1	1.2*	0.66	0.57	0.09	2.41 (1.20)	3.25 (1.80)	0.84 (0.60)
2	20.9	18.5	2.4*	2.52	2.22	0.30*	1.69 (1.15)	2.29 (1.85)	0.60 (0.70)*
3	31.9	28.9	3.0*	3.94	3.61	0.33*	2.09 (1.10)	2.57 (1.90)	0.48 (0.80)*
4	37.7	35.1	2.6*	4.56	4.36	0.20*	2.01 (1.15)	2.37 (1.85)	0.36 (0.70)*
5	47.8	42.9	4.9*	5.30	4.90	0.40*	1.88 (1.10)	2.54 (1.90)	0.66 (0.80)*
Plantation no. 2 planted in 1976									
1	11.3	9.9	1.4*	0.90	0.81	0.09	1.38 (1.00)	1.95 (2.00)	0.57 (1.00)*
2	25.0	22.3	2.7*	3.68	3.16	0.52*	2.02 (1.30)	2.41 (1.70)	0.39 (0.40)
3	35.6	32.9	2.7*	5.12	4.56	0.56*	2.75 (1.45)	2.77 (1.55)	0.02 (0.10)
4	48.8	45.8	3.0*	6.17	5.62	0.55*	1.95 (1.15)	2.39 (1.85)	0.44 (0.70)*
5	60.4	55.1	5.3*	6.88	6.25	0.63*	1.85 (1.00)	2.42 (2.00)	0.57 (1.00)*

[1]Asterisk indicates significant difference at the 0.05 level.
[2]Tree form based on score of 1.00 (best) to 9.00 (poorest).

plots were sprayed with Dursban by ground equipment in late August in addition to having the June application of carbofuran to insure foliage protection. The resulting defoliation was significantly higher in unprotected plots, but never exceeded 25 percent due to insecticide drift from adjacent aerially-treated plantations. Cottonwood leaf beetle numbers were low throughout the study period at the Eagle Lake Site. Although leafhopper counts during the first growing season at plantation 3 were significantly higher in unprotected plots (8.8 leafhoppers per terminal) than in protected plots (0.9 leafhopper per terminal), the degree of injury was light.

Plantations 5 and 6 (Lake Providence)

Height growth was significantly greater in protected plots than that in unprotected plots during the first and fifth years at plantation 5 and only during the first year at plantation 6 (table 4). Mean height advantages of protected plots over unprotected plots at the Lake Providence sites were small, ranging from yearly averages of 1.1 to 2.2 ft. for plantation 5 to only 1.2 to 1.3 ft. for plantation 6. Tree diameters were significantly larger in protected plots during 3 of 5 years at plantation 5 (0.09 to 0.25 in.) but only during the first year at plantation 6 (0.14 in.). Tree form was significantly better in protected plots than in unprotected plots 3 years out of 5 at plantation 5, but only during the first year at plantation 6. The tree form score for 1-year-old unprotected trees at plantation 5 exceeded the form score for protected trees by 1.10, the widest margin of any site or age. This large difference was attributed to terminal injury by insects, primarily the cottonwood twig borer. At plantation 6, tree form deteriorated noticeably with increasing numbers of forks, bushy tops, and crooks each year of growth, averaging a score of more than 4.0 in both protected and unprotected plots during the fourth year. The poor performance of trees in plantation 6 after four growing seasons was attributed to poor site (clay content of soil too high), and resulted in part of the plantation being cleared and planted to soybeans.

Insect numbers at both Lake Providence plantations were low with a couple of exceptions. The cottonwood twig borer was probably the most noticeable insect (fig. 2). Twig borer counts during the first year

Table 2.—*Number of cottonwood twig borer attacks per 18-inch terminal counted at the end of the first growing season*[1]

Plantation location	Mean no. of twig borers per 18-inch terminal		
	Protected	Unprotected	Difference
Fitler, MS			
Plantation 1	0.16	2.87	2.71*
Plantation 2	1.41	2.35	0.94
Eagle Lake, MS			
Plantation 3	0.18	0.72	0.54*
Plantation 4	1.24	1.57	0.33
Lake Providence, LA			
Plantation 5	4.21	14.09	9.88*
Plantation 6	0.43	0.89	0.46*

[1]Asterisk indicates significant difference at the 0.05 level.

at plantation 5 were moderately high in unprotected plots (14.09 borers per 18-in. terminal) and significantly higher than counts in protected plots (4.21 borers per 18-in. terminal) (table 2). The cottonwood leaf beetle also reached moderate levels. Before the June 1976 application of carbofuran, protected plots were given one application of Dursban at plantation 5 and two applications of Dursban at plantation 6. Resulting leaf beetle defoliation in unprotected plots reached 34 percent compared to 12 percent in protected plots at plantation 5 and 41 percent compared to 18 percent at plantation 6. Light aphid and leafhopper populations occurred during the first year of growth at both sites, but injury to trees was light.

All Plantations Combined

When all plots were combined, growth and tree form were only slightly better in plots protected from insects (table 5). For example, 5-year-old trees were only 3.8 ft. taller and 0.43 in. larger in diameter in protected plots than in unprotected plots. The best growth advantage occurred in plantation 2 at Fitler where growth in protected plots exceeded that in unprotected plots by 5.3 ft. in height and 0.63 in d.b.h. (table 1). Tree form was significantly better in protected plots but, again, actual differences were small.

Form in young trees appears to be influenced by both insect pests and tree vigor. Trees planted on suit-

Table 3.—*Impact of insects on the first five years of growth and tree form in young cottonwood plantations at Eagle Lake, MS*[1]

Age (Yrs)	Mean height (ft)			Mean d.b.h. (in)			Mean tree form score (rank)[2]		
	Protected	Unprotected	Diff.	Protected	Unprotected	Diff.	Protected	Unprotected	Difference
Plantation no. 3 planted in 1975									
1	10.1	8.6	1.5*	0.84	0.64	0.20*	2.30 (1.20)	2.99 (1.80)	0.69 (0.60)
2	27.1	25.6	1.5*	3.69	3.45	0.24*	2.10 (1.15)	2.43 (1.85)	0.33 (0.70)*
3	38.9	36.9	2.0*	5.75	5.48	0.27*	2.49 (1.25)	2.98 (1.75)	0.49 (0.50)
4	48.7	45.6	3.1*	6.83	6.37	0.46*	2.64 (1.20)	3.16 (1.80)	0.52 (0.60)
5	62.6	58.9	3.7*	8.16	7.66	0.50*	2.03 (1.15)	2.68 (1.85)	0.66 (0.70)*
Plantation no. 4 planted in 1976									
1	11.7	11.1	0.6*	1.02	0.93	0.09*	1.57 (1.00)	1.95 (2.00)	0.38 (1.00)*
2	23.3	22.1	1.2	3.49	3.30	0.19	2.20 (1.40)	2.64 (1.60)	0.44 (0.20)
3	32.6	32.1	0.5	5.13	5.08	0.05	3.19 (1.50)	3.08 (1.50)	−0.11 (0.00)
4	43.8	41.7	2.1*	6.62	6.41	0.21*	2.56 (1.40)	2.83 (1.60)	0.27 (0.20)
5	54.4	51.5	2.9*	7.58	7.20	0.38*	1.78 (1.15)	2.52 (1.85)	0.74 (0.70)*

[1]Asterisk indicates significant difference at the 0.05 level.
[2]Tree form based on score of 1.00 (best) to 9.00 (poorest).

Table 4.—*Impact of insects on the first five years of growth and tree form in young cottonwood plantations at Lake Providence, LA*[1]

Age (Yrs)	Mean height (ft)			Mean d.b.h. (in)			Mean tree form score (rank)[2]		
	Protected	Unprotected	Diff.	Protected	Unprotected	Diff.	Protected	Unprotected	Difference
Plantation no. 5 planted in 1975									
1	11.1	9.4	1.7*	0.96	0.87	0.09*	1.70 (1.20)	2.80 (1.80)	1.10 (0.60)*
2	22.7	21.6	1.1	2.53	2.38	0.15	1.69 (1.30)	2.46 (1.70)	0.77 (0.40)
3	32.7	30.9	1.8	3.89	3.72	0.17*	1.63 (1.15)	1.92 (1.85)	0.29 (0.70)*
4	38.8	37.0	1.8	4.65	4.44	0.21	1.83 (1.45)	1.89 (1.55)	0.06 (0.10)
5	48.0	45.8	2.2*	5.57	5.32	0.25*	1.96 (1.15)	2.28 (1.85)	0.32 (0.70)*
Plantation no. 6 planted in 1976[3]									
1	6.8	5.6	1.2*	0.41	0.27	0.14*	1.46 (1.00)	2.42 (2.00)	0.96 (1.00)*
2	15.1	13.9	1.2	1.61	1.38	0.23	2.63 (1.70)	2.37 (1.30)	−0.26 (−0.40)
3	18.3	17.0	1.3	2.46	2.19	0.27	3.68 (1.50)	3.78 (1.50)	0.10 (0.00)
4	24.6	23.3	1.3	3.25	2.93	0.32	4.12 (1.40)	4.28 (1.60)	0.16 (0.20)

[1]Asterisk indicates significant difference at the 0.05 level.
[2]Tree form based on score of 1.00 (best) to 9.00 (poorest).
[3]Plantation was cut after 4 years due to poor growth and planted to soybeans, thus no 5th year measurements were taken at this site.

Table 5.—*Summary (data combined for all sites) of insect impact on the first five years of growth and tree form in young cottonwood plantations at Fitler, MS, Eagle Lake, MS, and Lake Providence, LA*[1]

Age (Yrs)	Mean height (ft)			Mean d.b.h. (in)			Mean tree form score (rank)[2]		
	Protected	Unprotected	Diff.	Protected	Unprotected	Diff.	Protected	Unprotected	Difference
1	10.1	8.8	1.3*	0.80	0.68	0.12*	1.80 (0.60)	2.56 (1.20)	0.76 (0.60)*
2	22.4	20.7	1.7*	2.92	2.65	0.27*	2.06 (0.70)	2.43 (1.10)	0.37 (0.40)*
3	31.7	29.8	1.9*	4.38	4.11	0.27*	2.64 (0.70)	2.85 (1.10)	0.21 (0.40)*
4	40.4	38.1	2.3*	5.35	5.02	0.33*	2.52 (0.60)	2.82 (1.20)	0.30 (0.60)*
5	54.6	50.8	3.8*	6.70	6.27	0.43*	1.90 (0.50)	2.49 (1.00)	0.59 (0.50)*

[1]Asterisk indicates significant difference at the 0.05 level.
[2]Tree form based on score of 1.00 (best) to 9.00 (poorest).

able soils with good weed control were able to tolerate light to moderate insect injury and still develop suitable tree form (fig. 1). For example, trees often developed forks and other deformities when terminals were stunted or killed by insects (figs. 2–3). However, during subsequent growth on good sites, one side of a fork typically became dominant rather quickly, leaving the other side of a fork as a mere heavy branch or mild crook which became less noticeable with time (fig. 4). Only when a fork or crook persisted in the lower trunk was it considered serious. This observation was particularly evident in plantation 6 at Lake Providence, a poor site, where tree form progressively worsened each year of growth.

Tree mortality due to insect injury was negligible, as only 6 trees scattered among all plots died from insect damage. This mortality was attributed to cottonwood borers girdling the bark at the root collar during the first year of growth. Several other trees broke at borer infested sites on the trunk, but none died.

CONCLUSIONS

Impact of insects on early growth and development in young cottonwood plantations during this 5-year study was relatively light. However, it should be emphasized that insect populations during this same period also were low. Therefore, with insect populations similar to those occurring in plots during this study, little direct control in young plantations would be warranted. It is important to point out, however, that heavier insect populations will undoubtedly occur from time to time. Consequently, young plantations especially during the first three years of growth should be monitored periodically throughout the growing season for damaging infestations. Whenever insect populations threaten heavy defoliation, substantial loss of terminals, or tree mortality, then direct controls should be used.

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During the period of study, insect populations occurred only lightly, and their impacts on trees were also light; yet, impact differences between protected and unprotected plots were significant.

Additional keywords: *Populus deltoides*, losses.

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SUMMARY

Equations are given to estimate current and projected volumes and projected basal areas of uneven-aged shortleaf pine (*Pinus echinata* Mill.) stands managed under the selection system. The independent variables are initial merchantable basal area, initial sawtimber basal area, site index for shortleaf pine (base age 50), and elasped time. The results provide guidelines for basal area, cubic-foot, and board-foot volume production of uneven-aged shortleaf pine stands on different sites in the Interior Highlands of the West Gulf.

INTRODUCTION

Shortleaf pine (*Pinus echinata* Mill.) has the widest range of the southern pines. It is found in 22 states in an area greater than 440,000 square miles (Lawson and Kitchens 1983). It amounts to one-quarter of the southern pine volume, is exceeded only by loblolly pine (*P. taeda* L.), and outranks the combined volumes of slash (*P. elliottii* Engelm.) and longleaf (*P. palustris* Mill.) pines. The greatest concentration of shortleaf pine is found in the Interior Highlands of Arkansas and east Oklahoma (Sternitzke and Nelson 1970). It is the only naturally occurring pine in the Interior Highlands, and it is there that shortleaf management is concentrated.

Despite its importance as a resource, shortleaf has been the most neglected of the major southern pines in terms of research information. This is particularly true for growth and yield information. There is some growth and yield data available for natural even-aged stands (U.S. Department of Agriculture, Forest Service 1929, Brinkman et al. 1965; Schumacher and Coile 1960; Sander and Rogers 1979; Murphy and Beltz 1981; Murphy 1982) and plantations (Smalley and Bailey 1974). Though Murphy and Farrar (1982, 1983) and Farrar et al. (1984) developed information for uneven-aged loblolly-shortleaf pine, their data came from the West Gulf Coastal Plain where loblolly is predominant and usually preferred over shortleaf. Hence, shortleaf is usually a minor component in these stands. No models exist for uneven-aged stands where shortleaf is the predominant species, as in the Interior Highlands.

This paper presents a system of equations for predicting projected basal areas and current and projected volumes for selection-managed stands of shortleaf pine.

PROCEDURE

Data

The data come from permanent inventory plots located in Conway, Garland, Perry, Pulaski, Saline, and Yell counties in Arkansas.[1] Over 400 0.2-acre plots have been measured four times, in 1966, 1972, 1978, and 1982. Individual tree records were maintained for all trees 5.6 inches d.b.h. and larger. The pertinent information collected on shortleaf pine was the following: (1) d.b.h. to the nearest 0.1 inch; (2) merchantable length on pulpwood trees (5.6 to 8.5 inches d.b.h.), the length from a 0.5-foot stump to a 4-inch top, outside bark, to the nearest 5 feet with a five foot minimum; (3) sawlog length for sawtimber trees (8.6 inches d.b.h. and larger), the length from a 1-foot stump to a 6-inch top, outside bark, to the nearest even foot with a minimum length of 10 feet; (4) and merchantable length for sawtimber trees, the length from a 1-foot stump to a 4-inch top, outside bark, to the nearest 5 feet; (5) tree product class; and (6) tree history. Site index (base age 50) for shortleaf pine was also determined for each plot using Misc. Publ. 50 (U.S.D.A., Forest Service 1929).

[1]We thank Deltic Farm and Timber Co., Inc., of El Dorado, Arkansas, for kindly making these data available.

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Individual tree volumes were calculated in the following manner: Merchantable cubic-foot volumes, inside bark, for shortleaf pines 5.6 inches d.b.h. and larger from a 0.5-foot stump to a 4-inch-top, outside bark, were calculated using the equation

$$C_m = 0.00274D^2H_m + 0.2997$$

where

C_m = merchantable cubic-foot volume, i.b.,
D = diameter breast height, and
H_m = merchantable length to the nearest 5 feet from a 0.5-foot stump to a 4-inch top, outside bark.

Sawlog cubic-foot volumes, inside bark, for shortleaf pine sawtimber (8.6 inches d.b.h. and larger) from a 1-foot stump to a 6-inch top, outside bark, were determined by equation

$$C_s = 0.002774D^2H_s + 1.415 \ ,$$

where

C_s = sawtimber cubic-foot volume,
D = diameter breast height, and
H_s = sawlog length to the nearest even foot from a 1-foot stump to a 6-inch top, outside bark.

Board-foot volumes for the Doyle, Scribner, and International 1/4-inch rules were calculated using the following taper assumptions. For the first 16-foot log, a Girard form class of 82 was used; for the second log, a taper of 2.1 inches was used; and for the third and subsequent logs, a taper of 3.2 inches was used. A 0.3-foot trim allowance was used for each 16-foot log and the top fractional log.

The following plot variables were calculated on a per-acre basis for shortleaf pine:

B_{mi} = the merchantable basal area in trees, 5.6 inches d.b.h. and larger, present at time i,

B_{si} = the sawtimber basal area in trees, 8.6 inches d.b.h. and larger, present at time i,

V_{mi} = merchantable cubic-foot volume, inside bark, in trees, 5.6 inches d.b.h. and larger, from a 0.5-foot stump to a 4-inch top, outside bark, to the nearest 5 feet at time i,

V_{si} = sawtimber cubic-foot volume, inside bark, in trees, 8.6 inches d.b.h. and larger, from a 1-foot stump to a 6-inch top, outside bark, to the nearest even foot at time i,

D_i = board-foot volume, Doyle rule, in trees, 8.6 inches d.b.h. and larger, from a 1-foot stump to a 6-inch top, outside bark, to the nearest even foot at time i,

S_i = board-foot volume, Scribner rule, in trees, 8.6 inches d.b.h. and larger, from a 1-foot stump to a 6-inch top, outside bark, to the nearest even foot at time i,

I_i = board-foot volume, International 1/4-inch rule, in trees, 8.6 inches d.b.h. and larger, from 1-foot stump to a 6-inch top, outside bark, to the nearest even foot at time i.

Also,

Q = site index (shortleaf pine, base age 50) of plot in feet.

Summarizing the data resulted in 1,338 growth observations. To assure that the plots were predominantly shortleaf and uneven-aged in character, only those that were classified as being a pine type and having a pine understory, a pine overstory, and pine reproduction were used. Even with these restrictions, most plots had a minor hardwood component. Observations of plots that were cut during a growth period or had an excess of 10 percent mortality in merchantable basal area were deleted. Because the data were concentrated in a few site index and basal area classes, a restricted set of observations were randomly chosen to obtain a more uniform sample across the range of the data. This selection reduced the total observations used to 149. Table 1 shows the distribution of the plots.

Analysis

A stand level growth and yield prediction system consists of stand volume equations plus one or more basal area projection equations. Directly determined variables, such as present basal area, are used to estimate volumes of current stands. For future volumes, however, some variables—such as future basal area—must themselves be predicted before future volumes can be estimated.

The equation for projected merchantable basal area has been previously used by Moser and Hall (1969) and Murphy and Farrar (1982) for other uneven-aged conditions. It is

$$B_{m2} = [k_1 - \{k_1 - B_{m1}{}^{k_3}\}e^{k_2k_3t}]^{1/k_3} \ ,$$

where

B_{m1} = merchantable basal area per acre at time 1,
B_{m2} = merchantable basal area per acre at time 2,
t = elapsed time in years between times one and two, and
k_i = coefficients to be estimated.

Since projected sawtimber volumes are of as much interest as merchantable volume, a sawtimber basal area projection equation was also incorporated into the equation system. It is an uneven-aged adaptation of an equation originally formulated for even-aged conditions (Murphy 1983) and is:

$$B_{s2} = B_{m2}[1 - \{1 - (B_{s1}/B_{m1})^{n_2}\}e^{n_1 n_2 t}]^{1/n_2} ,$$

where

B_{s1} = sawtimber basal area per acre at time 1,
B_{s2} = sawtimber basal area per acre at time 2,
n_i = coefficients to be estimated,

and the other variables are as previously defined. The equation for merchantable volume is

$$V_{mi} = b_0 B_{mi}^{b_1} e^{b_2 Q} ,$$

where

V_{mi} = merchantable cubic volume per acre at time i,
B_{mi} = merchantable basal area per acre at time i,
Q = site index (shortleaf pine, base age 50), and
b_i = coefficients to be estimated.

The generalized equation for sawtimber volumes is

$$Z_{si} = c_0 B_{si}^{c_1} e^{c_2 Q} ,$$

Table 1.—*Plot distribution by shortleaf merchantable basal area, sawtimber basal area, and site index (base age 50) set at time one*

Site index	Merchantable basal area	Sawtimber basal area (ft^2)					
		<11	11–29	30–49	50–69	70–89	Total
ft	*ft^2*	*number of plots*					
<45	<11	3					3
	11–29	3	4				7
	30–49	...	4	2			6
	50–69	...	.....	2	.....		2
	70–89	1	.....	.....	.....	.....	1
	>89	...	.....	.....	.....	.....	0
	Total	7	8	4	0	0	19
46–55	<11	7					7
	11–29	7	7				14
	30–49	2	7	6			15
	50–69	...	1	7	2		10
	70–89	...	.....	1	3	1	5
	> 89	...	.....	.....	.....	.....	0
	Total	16	15	14	5	1	51
56–65	<11	7					7
	11–29	7	7				14
	30–49	2	7	7			16
	50–69	...	3	7	2		12
	70–89	...	.....	1	3	.....	4
	>89	...	.....	.....	1	.....	1
	Total	16	17	15	6	0	54
>65	<11	3					3
	11–29	2	5				7
	30–49	1	6	4			11
	50–69	...	1	2	1		4
	70–89	...	.....	.....	.....	.....	0
	>89	...	.....	.....	.....	.....	0
	Total	6	12	6	1	0	25
All sites	<11	20					20
	11–29	19	23				42
	30–49	5	24	19			48
	50–69	...	5	18	5		28
	70–89	1	.....	2	6	1	10
	>89	...	.....	.....	1	.....	1
	Total	45	52	39	12	1	149

where

Z_{si} = sawtimber volume per acre of interest at time i
c_i = coefficients to be estimated,
B_{si} = sawtimber basal area at time i,

and the other variables are as previously defined. The volumes of interest are sawtimber cubic-foot volumes per acre and board-foot volumes per acre for the Doyle, Scribner, and International 1/4-inch log rules.

The coefficients were estimated by nonlinear least squares (SAS Institute 1982). The resulting equations are:

(1) $B_{m2} = [1.7819 - \{1.7819 - B_{m1}^{0.11699}\}e^{-0.36313(0.11699)t}]^{(1/0.11699)}$

(2) $B_{s2} = B_{m2}[1 - \{1 - (B_{s1}/B_{m1})^{1.5036}\}e^{-0.017286(1.5036)t}]^{(1\ 1.5036)}$

(3) $V_{mi} = 9.6209B_{mi}^{1.1200}e^{0.0031623Q}$,

(4) $V_{si} = 10.030B_{si}^{1.1554}e^{0.0017908Q}$,

(5) $D_i = 16.327B_{si}^{1.2944}e^{0.0070266Q}$,

(6) $S_i = 37.227B_{si}^{1.2333}e^{0.0046645Q}$,

(7) $I_i = 43.258B_{si}^{1.2363}e^{0.0041047Q}$,

To evaluate the model, the predicted values were compared with the corresponding observed values. The results are in table 2. The basal area projection equations have little bias. Estimates of current merchantable cubic-foot volumes overpredict somewhat, and projected merchantable volumes are negatively biased. The equations for all other volume estimates overpredict slightly for current volumes, and the overpredictions are less pronounced for projected volumes. All the equations were deemed to predict with adequate precision.

APPLICATION

Use of Tables

To illustrate the use of the accompanying tables, suppose it is decided to manage an uneven-aged shortleaf pine stand on land with a site index of 60 feet on a 7-year cutting cycle. The densities at the start of the cutting cycle are 60 and 45 square feet for merchantable and sawtimber basal areas, respectively. What will be the cyclic harvest under this management regime?

The first step is to obtain estimates of current volume. Looking at table 3, we find that the mer-

Table 2.—*Evaluation of prediction equations*

Variable	Fit index[1]	Observed mean value	Bias[2]	Absolute deviation[3] Mean	Absolute deviation[3] Standard deviation
			ft²		
B_{m2}	0.92	47.2	0.2	5.2	4.0
B_{s2}	0.92	31.2	−1.7	4.4	2.8
			ft³, i.b.		
V_{m1}	0.90	639	−20	97	89
V_{m2}	0.93	898	22	97	97
V_{s1}	0.93	422	−16	58	62
V_{s2}	0.91	629	−14	93	78
			fbm		
D_1	0.84	1,482	−58	337	351
D_2	0.85	2,325	−8	431	554
S_1	0.89	2,403	−89	417	453
S_2	0.88	3,676	−49	605	692
I_1	0.89	2,728	−110	487	519
I_2	0.88	4,191	−53	689	776

[1] $I^2 = 1 - \Sigma(y_i - \hat{y}_i)^2/\Sigma(y_i - \bar{y})^2$
[2] Bias = $\Sigma(y_i - \hat{y}_i)/n$
[3] Absolute deviation = $|y_i - \hat{y}_i| = d_i$
Mean = $\Sigma d_i/n$
Standard deviation = $\sqrt{[\Sigma d_i^2 - (\Sigma d_i)^2/n]/(n-1)}$

where
y_i = observed value,
$\hat{y}_i$ = predicted value, and
n = 149, the number of observations.

chantable volume per acre is 1,141 cubic feet. Table 4 contains sawtimber volumes, and the estimates are found by interpolating between 40 and 50 square feet of sawtimber basal area. Current volumes are 909 cubic feet; 3,443 board feet (Doyle rule); 5,396 board feet (Scribner rule); and 6,133 board feet (International 1/4-inch rule).

Projected volumes and basal areas are to be determined next, enabling us to then determine projected volumes. Projected basal areas are determined first. An initial merchantable basal area of 60 square feet and a projection period of 7 years yields a projected basal area of 75 square feet (table 5). These initial merchantable and sawtimber basal areas are needed to derive projected sawtimber basal area in table 6.

Table 3.—*Merchantable cubic-foot volume per acre for uneven-aged stands of shortleaf pine for different merchantable basal areas and site indexes*

Merchantable basal area	Site index (ft)			
	50	60	70	80
ft^2	---------- ft^3, i.b. ----------			
30	508	525	542	559
40	702	724	748	772
50	901	930	960	991
60	1,105	1,141	1,177	1,215
70	1,313	1,356	1,399	1,444
80	1,525	1,574	1,625	1,677
90	1,740	1,796	1,854	1,914

Table 4.—*Sawtimber volumes per acre for uneven-aged stands of shortleaf pine for different sawtimber basal areas and site indexes*

Sawtimber basal area	Sawlog volume	Board-foot volume		
		Doyle	Scribner	International 1/4-inch
ft^2	ft^3, i.b.	---------- fbm ----------		
Site index 50				
20	349	1,121	1,891	2,156
30	558	1,894	3,118	3,559
40	778	2,749	4,446	5,080
50	1,007	3,670	5,854	6,693
60	1,244	4,647	7,331	8,385
70	1,486	5,673	8,866	10,146
80	1,734	6,743	10,453	11,967
Site index 60				
20	356	1,202	1,981	2,246
30	568	2,032	3,267	3,708
40	792	2,949	4,658	5,292
50	1,026	3,937	6,134	6,974
60	1,266	4,985	7,681	8,737
70	1,513	6,086	9,289	10,571
80	1,765	7,234	10,952	12,469
Site index 70				
20	362	1,290	2,076	2,341
30	579	2,180	3,423	3,864
40	807	3,164	4,881	5,514
50	1,044	4,223	6,427	7,266
60	1,289	5,348	8,047	9,103
70	1,540	6,529	9,732	11,014
80	1,797	7,760	11,475	12,991
Site index 80				
20	369	1,384	2,175	2,439
30	589	2,339	3,586	4,026
40	821	3,394	5,114	5,745
50	1,063	4,531	6,734	7,570
60	1,312	5,737	8,432	9,484
70	1,568	7,004	10,197	11,476
80	1,830	8,325	12,023	13,535

Projected sawtimber basal area is found by interpolating between the projected values for initial sawtimber basal areas of 40 and 50 feet—which are 55 and 65 square feet, respectively. Projected sawtimber basal area is thus 60 square feet. Merchantable cubic-foot volume in 7 years is found by using the projected merchantable basal area (from table 5) and linear interpolation in table 3; it is 1,465 cubic feet. Sawtimber volumes are similarly found by consulting table 4 where sawtimber basal area is 60 square feet. They are 1,266 cubic feet; 4,985 board feet (Doyle rule); 7,681 board feet (Scribner rule); and 8,737 board feet (International 1/4-inch rule).

Basal area growth for the period is 2 square feet per acre per year for both sawtimber and merchantable basal areas. Annual per-acre volume growth is 46 cubic feet for merchantable volume; 51 cubic feet for sawtimber; and 220, 326, and 372 board feet for the Doyle, Scribner, and International 1/4-inch rules, respectively.

Use of Equations

These growth and yield models can also be used for other purposes. Many private nonindustrial timberlands brought under management are understocked. The problem is to increase stocking while simultaneously providing the landowner a periodic income under a variety of constraints. One common harvesting constraint is that there must be an operable cut of, say, at least a thousand board feet per acre (Doyle rule). The models can be used to derive a management strategy with these objectives and constraints.

For example, suppose a tract of uneven-aged shortleaf pine is to be brought under management. The site index for shortleaf is 70 feet (base age 50) on the property, and the current stand has 45 square feet in merchantable basal area and 25 square feet in sawtimber basal area. The desired management regime is a 7-year cutting cycle and residual densities of 60 and 45 square feet for merchantable and sawtimber basal areas, respectively. How might this property be managed to bring the stand up to these stocking goals while providing a periodic cut that is at least 1,000 board feet (Doyle rule)?

A proposed strategy is to maintain a 7-year cutting cycle and to cut 75 percent of growth and see if the harvesting constraint is followed. In this illustration, equations will be used instead of tables.

The present stand will be allowed to grow 7 years and then be harvested. To determine merchantable basal area in 7 years, equation (1) is used,

$$B_{m2} = [1.7819 - \{1.7819 - 45^{0.11699}\}e^{-0.36313(0.11699)7}]^{(1/0.11699)},$$
$$= 61.1 \text{ square feet}.$$

The periodic growth is 61.1 − 45.0 or 16.1 square feet. If 75 percent of periodic growth is to be harvested, then 12.1 square feet of merchantable basal area will be cut, and the residual density is 49.0 square feet. Equation (1) is used again to project basal area for 7 years, and the whole process is repeated until the stocking goal is reached. The following table summarizes the cyclic harvests and residual densities for merchantable basal area:

Table 5.—*Projected merchantable basal area per acre for uneven-aged shortleaf pine stands for different elapsed times and initial merchantable basal areas*

	Initial merchantable basal area (ft^2)						
Elapsed time	30	40	50	60	70	80	90
years	----------	----------	----------	ft^2	----------	----------	----------
1	32	42	52	62	72	82	92
2	34	45	55	64	74	84	93
3	37	47	57	67	76	86	95
4	39	49	59	69	78	87	97
5	41	52	61	71	80	89	98
6	43	54	64	73	82	91	100
7	46	56	66	75	84	93	101
8	48	58	68	77	86	94	102
9	50	61	70	79	88	96	104
10	53	63	72	81	89	97	105

Merchantable Basal Area

Time	Before cut	Cut	After cut
years	----------	ft^2	----------
0	45.0	. . .	45.0
7	61.1	12.1	49.0
14	64.9	11.9	53.0
21	68.7	11.8	56.9
28	72.3	12.3	60.0
35	75.1	15.1	60.0

The residual stocking goal for merchantable basal area is reached in 28 years, and regular cyclic cuts for merchantable basal area and volume occur after that.

The cutting schedule for sawtimber basal area is computed next. The projected sawtimber basal area in 7 years, given initial basal areas of 45 square feet for mechantable trees and 25 square feet for sawtimber trees, is determined by equation (2),

$$B_{s2} = 61.1[1 - \{1 - (25/45)^{1.5036}\}e^{-0.017286(1.5036)7}]^{(1/1.5036)},$$
$$= 39.1 \text{ square feet}.$$

The periodic growth is 39.1 − 25.0 or 14.1 square feet per acre, and the first cycle cut for sawtimber basal area is 75 percent of periodic growth: 10.6 square feet. Values for subsequent cutting cycles are determined in the same manner, and the following table may be constructed:

Table 6.—*Projected sawtimber basal area per acre for uneven-aged stands of shortleaf pine for different elapsed times, initial merchantable basal areas, and initial sawtimber basal areas*

Elapsed time	Initial merchantable basal area	Initial sawtimber basal area (ft^2)							
		20	30	40	50	60	70	80	90
years	ft^2	ft^2							
1	30	22	32						
	40	22	32	42					
	50	22	32	42	52				
	60	22	32	42	52	62			
	70	23	32	42	52	62	72		
	80	23	32	42	52	62	72	82	
	90	23	33	42	52	62	72	82	92
2	30	24	34						
	40	24	34	45					
	50	24	34	44	55				
	60	24	34	44	54	64			
	70	25	35	44	54	64	74		
	80	26	35	44	54	64	74	84	
	90	26	35	45	54	64	74	84	93
3	30	25	37						
	40	26	36	47					
	50	26	36	46	57				
	60	27	36	46	56	67			
	70	27	37	46	56	66	76		
	80	28	37	47	56	66	76	86	
	90	29	38	47	56	66	76	85	95
4	30	27	39						
	40	27	38	49					
	50	28	38	49	59				
	60	29	38	48	59	69			
	70	30	39	49	58	68	78		
	80	31	40	49	58	68	78	87	
	90	32	41	49	59	68	77	87	97
5	30	29	41						
	40	29	40	52					
	50	30	40	51	61				
	60	31	41	50	61	71			
	70	32	41	51	60	70	80		
	80	34	42	51	60	70	79	89	
	90	35	43	52	61	70	79	89	98
6	30	31	43						
	40	31	42	54					
	50	32	42	53	64				
	60	33	43	53	63	73			
	70	35	43	53	62	72	82		
	80	36	44	53	62	72	81	91	
	90	38	46	54	63	72	81	90	100
7	30	33	46						
	40	34	45	56					
	50	34	44	55	66				
	60	36	45	55	65	75			
	70	37	46	55	64	74	84		
	80	39	47	55	64	74	83	93	
	90	40	48	56	65	73	82	92	101
8	30	35	48						
	40	36	47	58					
	50	37	47	57	68				
	60	38	47	57	67	77			
	70	40	48	57	66	76	86		

Table 6.—*Projected sawtimber basal area per acre for uneven-aged stands of shortleaf pine for different elapsed times, initial merchantable basal areas, and initial sawtimber basal areas—(Continued)*

Elapsed time	Initial merchantable basal area	Initial sawtimber basal area (ft^2)							
		20	30	40	50	60	70	80	90
years	ft^2	---------- ft^2 ----------							
	80	41	49	57	66	75	85	94	
	90	43	50	58	67	75	84	93	102
9	30	37	50						
	40	38	49	61					
	50	39	49	59	70				
	60	40	49	59	69	79			
	70	42	50	59	68	78	88		
	80	44	51	59	68	77	86	96	
	90	46	53	60	68	77	86	95	104
10	30	40	53						
	40	40	51	63					
	50	41	51	61	72				
	60	42	51	61	71	81			
	70	44	52	61	70	80	89		
	80	46	53	61	70	79	88	97	
	90	48	55	62	70	79	87	96	105

Sawtimber Basal Area

Time	Before cut	Cut	After cut
years	---------- ft^2 ----------		
0	25.0	. . .	25.0
7	39.1	10.6	28.5
14	42.9	10.8	32.1
21	46.6	10.9	35.7
28	50.3	11.0	39.3
35	53.9	11.0	42.9
42	57.6	12.6	45.0
49	59.7	14.7	45.0

The residual stocking goal for sawtimber basal area is reached in 42 years, two cutting cycles later than for merchantable basal area. The cyclic harvest for sawtimber basal area is 14.7 square feet after the stocking goal is reached.

Now that merchantable and sawtimber basal areas have been determined, volumes can be calculated. Merchantable volumes are calculated using equation (3). The initial volume is

$$V_m = 9.6209[45]^{1.1200}e^{0.0031623(70)} ,$$
$$= 853 \text{ cubic feet} .$$

The volume in 7 years is determined by substituting the projected merchantable basal area, which is 61.1 square feet,

$$V_m = 9.6209[61.1]^{1.1200}e^{0.0031623(70)} ,$$
$$= 1,201 \text{ cubic feet} .$$

The residual volume is found by using the residual merchantable basal area 49.0 square feet in equation (3),

$$V_m = 9.6209[49.0]^{1.1200}e^{0.0031623(70)} ,$$
$$= 938 \text{ cubic feet} .$$

The harvest is determined by subtracting after-cut from before-cut volumes. The remaining values are determined in like manner. The following tabulation can now be constructed for merchantable cubic-foot volume:

Merchantable Cubic-foot Volume

Time	Before cut	Cut	After cut
years	---------- ft^3, *i.b.* ----------		
0	853	0	**853**
7	1,201	263	**938**
14	1,285	260	**1,025**
21	1,370	261	**1,109**
28	1,451	274	**1,177**
35	1,514	337	**1,177**

After the stocking goal is reached in year 28, the cyclic harvest for merchantable volume is 337 cubic feet. Periodic annual growth is 48 cubic feet.

Sawtimber cubic-foot volumes are determined by equation (4). The cubic volume for sawtimber at time zero is,

$$V_s = 10.030[25]^{1.1554}e^{0.0017908(70)} ,$$
$$= 469 \text{ cubic feet} .$$

Subsequent volumes and cuts are determined by following the procedures already developed. When these have been calculated, the following table can be developed:

Sawtimber Cubic-foot Volume

Time	Before cut	Cut	After cut
years		*ft³, i.b.*	
0	469	0	469
7	786	241	545
14	875	249	626
21	962	255	707
28	1,051	260	791
35	1,139	264	875
42	1,230	306	924
49	1,281	357	924

After the stocking goal for sawtimber is reached in year 42, the periodic cut will be 357 cubic feet for sawtimber. Periodic annual growth is 51 cubic feet.

Board-foot volumes for the Doyle rule are calculated using equation (5). The initial volume for the Doyle rule is

$$D = 16.327(25)^{1.2944}e^{0.0070266(70)} ,$$
$$= 1{,}722 \text{ board feet} .$$

After the volumes for the remainder of the planning period are calculated, the following tabulation can be assembled:

Doyle Board-foot Volume

Time	Before cut	Cut	After cut
years		*fbm*	
0	1,722	0	1,722
7	3,072	1,032	2,040
14	3,464	1,084	2,380
21	3,855	1,124	2,731
28	4,256	1,164	3,092
35	4,655	1,191	3,464
42	5,072	1,387	3,685
49	5,313	1,628	3,685

After the residual stocking goal is reached, the periodic cut is 1,628 board feet (Doyle rule), and the periodic annual growth is 233 board feet per acre. Notice that all the cuts are more than 1,000 board feet, so the harvesting constraint is satisfied by this management strategy.

The following harvest schedule for sawtimber volume for the Scribner was determined using equation (6):

Scribner Board-foot Volume

Time	Before cut	Cut	After cut
years		*fbm*	
0	2,734	0	2,734
7	4,746	1,533	3,213
14	5,321	1,600	3,721
21	5,892	1,650	4,242
28	6,474	1,698	4,776
35	7,051	1,730	5,321
42	7,652	2,008	5,644
49	7,998	2,354	5,644

The periodic cut is 2,354 board feet (Scribner rule) after the residual stocking goal is reached, and periodic annual growth is 336 board feet.

Finally, the board-foot volumes, International 1/4-inch rule, were calculated using equation (7).

International 1/4-inch Board-foot Volume

Time	Before cut	Cut	After cut
years		*fbm*	
0	3,084	0	3,084
7	5,361	1,736	3,625
14	6,013	1,812	4,201
21	6,660	1,869	4,791
28	7,320	1,925	5,395
35	7,973	1,960	6,013
42	8,655	2,277	6,378
49	9,047	2,669	6,378

After the cyclic harvest levels are stabilized, the periodic cut is 2,669 board feet (International 1/4-inch rule). Periodic annual growth is 381 board feet.

A variety of other strategies could have been used to rehabilitate the stand. For example, half of growth could be cut provided that the harvest was at least 1,000 board feet (Doyle rule). If an operable volume was not present, the cycle cut could be deferred. The cutting cycle length in this case would be variable in length. The potential applicability of these growth and yield models is limited only by the imagination of the user.

A program to use these growth and yield models on the TI-59[2] programmable calculator is available from the authors upon request. Also available is a listing of an example worksheet and cell contents for using the

models in the electronic spreadsheet program SuperCalc.[2] The SuperCalc output for the foregoing example is shown in the appendix. Some corresponding values differ slightly due to differences in the text example and those used in the spreadsheet program.

CONCLUSIONS

Users should consider several factors when using these models. First, the data came from plots that exhibited a well-defined uneven-aged structure with shortleaf pine present as overstory, understory, and reproduction. Plots were also defined as being in the shortleaf pine forest type. Therefore, these equations should be restricted to these kinds of conditions.

Merchantable basal areas and volumes are for shortleaf pine trees 5.6 inches d.b.h. and larger; sawtimber basal areas and volumes, 8.6 inches d.b.h. and larger. Merchantability standards for both merchantable and sawtimber volumes should also be consulted.

Projected basal areas do include ingrowth, and the amount of ingrowth reflects average conditions represented in the data. Basal area predictions will be inaccurate in situations in which there is little ingrowth or where a large amount of shortleaf pines less than 5.6 inches d.b.h. are present and capable of contributing a large amount of ingrowth.

Projection periods should be limited to 10 years or less. Table 1 should also be consulted to see if your stand conditions are represented. If your stands are outside the range of the sample data or another geographic area is involved, the results should be treated with caution and validated if possible.

Shortleaf pine in the Interior Highlands is an important resource, and the results presented here provide data heretofore unavailable about the growth and yield of this species in uneven-aged stands. This information should be valuable to forest managers who would consider this management option but have been hampered by the previous lack of growth and yield data.

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[2]TI-59 is a trademark of Texas Instruments, and SuperCalc is a trademark of Sorcim Corporation. The use of trade, firm, or corporation names is for the information and convenience of the reader. Such use does not constitute official endorsement or approval of the product or firm by the USDA to the exclusion of others which may be suitable.

Appendix—Shortleaf Pine Growth and Yield

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	U-A Shl.:	USh16YD				BEFORE-CUT						AFTER-CUT		
2														
3	Time	S.I.		Bm	MerCF	Bs	SawCF	Doyle		Bm	MerCF	Bs	SawCF	Doyle
4														
5	0	80		45.00	880	25.00	477	1847		45.00	880	25.00	477	1847
6														
7	7	80		61.08	1240	39.08	799	3293		49.00	969	28.50	555	2189
8														
9	14	80		64.93	1328	42.86	890	3711		53.00	1057	32.10	637	2553
10														
11	21	80		68.71	1414	46.64	981	4141		56.90	1145	35.70	720	2930
12														
13	28	80		72.32	1498	50.34	1071	4570		60.00	1215	39.30	805	3318
14														
15	35	80		75.14	1563	53.95	1161	4999		60.00	1215	42.90	891	3716
16														
17	42	80		75.14	1563	57.56	1251	5437		60.00	1215	45.00	941	3953
18														
19	49	80		75.14	1563	59.68	1304	5698		60.00	1215	45.00	941	3953
20														
21	56	80		75.14	1563	59.68	1304	5698						
22														
23														
24														
25														
26														
27														
28														
29														

	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
1						CUT						P. A. I.		
2														
3	Time	S.I.		Bm	MerCF	Bs	SawCF	Doyle		Bm	MerCF	Bs	SawCF	Doyle
4														
5	0	80		.00	0	.00	0	0						
6														
7	7	80		12.08	271	10.58	244	1104		2.30	51.33	2.01	46.04	207
8														
9	14	80		11.93	270	10.76	253	1158		2.28	51.29	2.05	47.76	218
10														
11	21	80		11.81	269	10.94	261	1212		2.24	50.96	2.08	49.13	227
12														
13	28	80		12.32	283	11.04	266	1253		2.20	50.39	2.09	50.14	234
14														
15	35	80		15.14	348	11.05	270	1283		2.16	49.76	2.09	50.82	240
16														
17	42	80		15.14	348	12.56	310	1483		2.16	49.76	2.09	51.45	246
18														
19	49	80		15.14	348	14.68	363	1744		2.16	49.76	2.10	51.87	249
20														
21	56	80								2.16	49.76	2.10	51.87	249
22														
23			CUT =	93.57	2138	81.61	1967	9238						
24														
25			CHANGE =	30.14	683	34.68	827	3850						
26														
27			YIELD =	123.72	2821	116.29	2794	13089						
28														
29			M.A.I. =	2.21	50.38	2.08	49.89	234						

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Murphy, Paul A.; Farrar, Robert M., Jr. Growth and yield of uneven-aged shortleaf pine stands in the Interior Highlands. Res. Paper SO-218. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1985. 11 p.

Equations are given to estimate current and projected volumes and projected basal areas of uneven-aged shortleaf pine (*Pinus echinata* Mill.) stands managed under the selection system.

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Predicting Stand and Stock Tables from a Spacing Study in Naturally Regenerated Longleaf Pine

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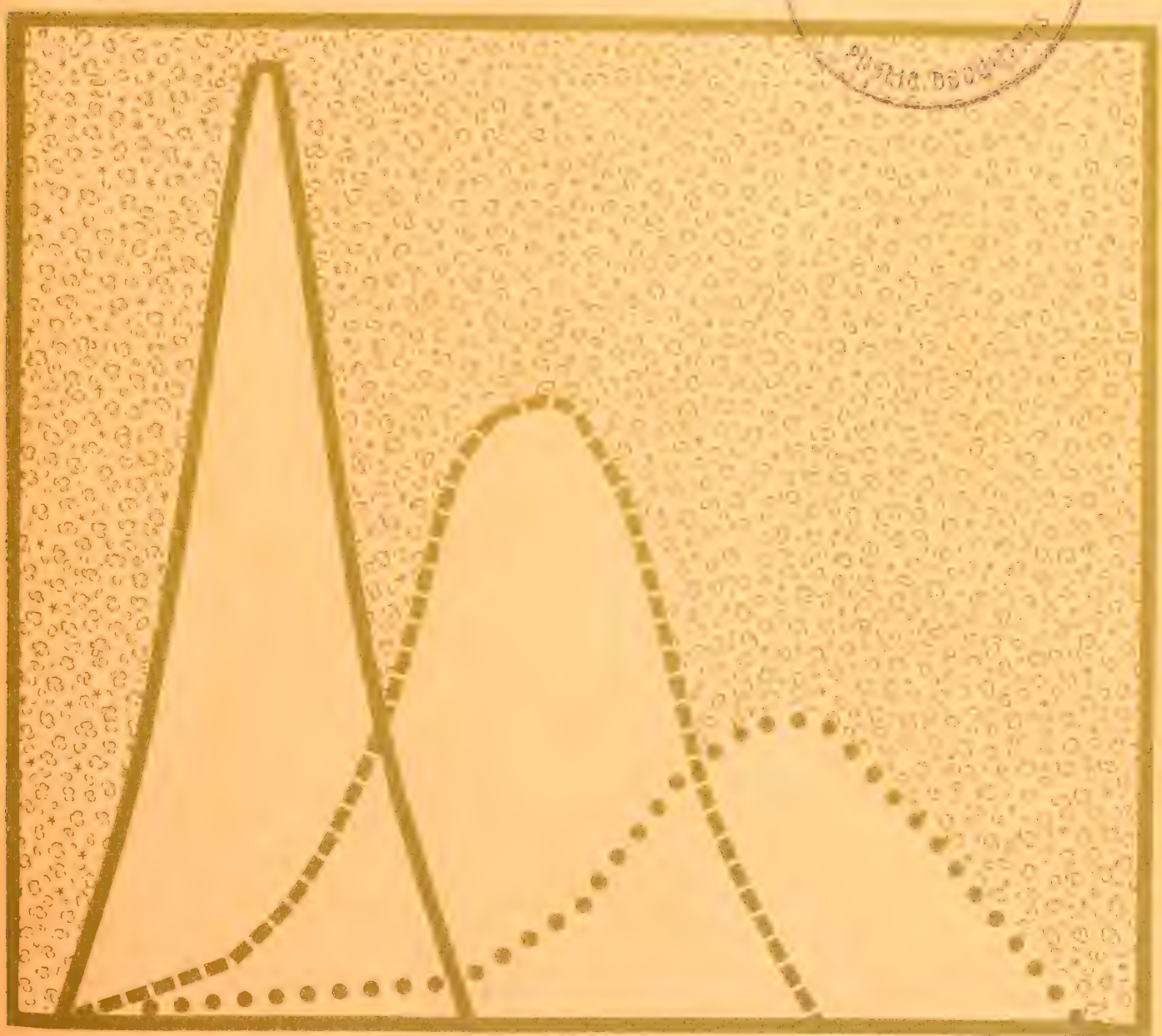

SUMMARY

A prediction system is presented whereby stand and stock tables are calculated for young natural longleaf pine stands of varying initial density. Tables can be output for stand conditions of 10 to 20 years of age, 300 to 1,500 initial trees per acre (at age 10), and 70 to 80 feet in site index (index age 50). The system also allows one to translate from density expressed as trees per acre at an age between 10 and 20 years to basal area at age 20 and thereby gain entry to another stand volume prediction and projection system for thinned natural longleaf pine that is operable for stand ages of 20 years and older.

Predicting Stand and Stock Tables from a Spacing Study in Naturally Regenerated Longleaf Pine

Robert M. Farrar, Jr.

INTRODUCTION

Stand volume and volume growth prediction systems for natural, even-aged stands of southern pines usually use basal area as the stand density variable, and predictions usually are not feasible before about 20 years of age. Basal area is a very practical density measure for stands about this age or older but not very informative or useful if stands are younger, especially if many of the trees are less than 4-1/2 feet tall. Since intensive management calls for volume and growth information at these younger ages, methods are needed to translate from one density measure at an early age (such as trees per acre) to basal area at a later age. The following paper outlines a system developed to do this for young stands of natural longleaf pine (*Pinus palustris* Mill.) by predicting stand and stock tables.

METHODS

Study Area

The data were gathered from a natural stand spacing study initiated in the winter of 1967–68 on the Escambia Experimental Forest in south Alabama. The study area was a 40-acre stand of dense, even-aged young longleaf pines, resulting principally from seed-tree regeneration in 1957 and 1958. Seed-trees were removed in 1961. In 1963, stand density ranged from about 3,000 to 8,000 trees per acre and averaged about 6,000. In 1967, when the study was installed, the stand was 9 to 10 years old from seed. Tree sizes then ranged from grass-stage seedlings to trees about 3 inches in d.b.h. and 20 feet tall. Dominant and codominant trees averaged 6 to 10 feet in height. The soil of the area is Alaga loamy sand, which is common on ridges and upper slopes in the rolling middle Gulf Coastal Plain. At about age 20, the site index (Farrar 1973) estimated on study plots ranged from 71 to 86 feet at 50 years and averaged 79 feet.

Treatments

Five tree-frequency densities were replicated three times on 1/5-acre permanent plots with 1/2-chain isolation strips in a completely randomized design. Residual densities of exactly 300, 600, 900, 1,200, and 1,500 trees per acre were initially established by manually cutting the trees that appeared poorest in vigor. No record was kept of the numbers of trees removed. All hardwoods with d.b.h. $\geq$ 1 inch were killed during the summer of 1968, and the study area was prescription burned in the winters of 1973–74, 1975–76, and 1977–78. No subsequent thinnings have been made.

Inventory

All trees on the 1/5-acre net plot were positively and permanently identified. Their d.b.h. was measured to the nearest one-tenth inch on all trees taller than breast height, and a systematic sample was made of total heights and heights to the live crown base by measuring these heights on every sixth tree in each 1-inch d.b.h. class (including the zero class) to the nearest foot. At least 2 trees were measured per d.b.h. class, if available, and at least 10 were measured per plot. Inventories were repeated at 2-year intervals and occurred in the dormant season. In the winter of 1973–74, at about stand age 15 years, all dominant and codominant sample trees were bored at 4 feet to determine age (age = ring count + 7 years). At least five trees were aged per plot. The mean age determined in this fashion agreed closely with the historical records of reproduction on the area. The last inventory reported on herein was made in the winter of 1977–78.

Analysis

Rather than analyze the stand characteristics and volume production data to simply detect any significant discrete differences among treatments, it was decided to employ techniques used to generate pre-

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dicted stand and stock tables for unthinned pine plantations in relation to stand age, site index, and density. This would allow predictions for a range of stand conditions (bounded by the limits of the data) rather than simple treatment means. This approach necessitated the development of the following six groups of prediction system components by site index and age at the stand level and/or at the d.b.h. class level.

1. A stand-level predictor (eq. 3a)[1] for mean dominant height (dominant and codominant trees) that uses a published site-index function to widen its utility. The published site-index function chosen (Farrar 1973) was the one for natural longleaf from USDA Miscellaneous Publication 50 (U.S. Forest Service 1976), hereafter called MP50, because the trends of dominant height observed in the study followed this MP50 function better than other available site-index functions. A given MP50 site-index value at index age 50 for a stand is translated to MP50 site index at index age 20 (eq. 1). This latter value is used with the dominant height function (eq. 3d) developed from study data to extend the dominant height estimates from age 20 down to age 10 (eq. 3a). The MP50 function could not be used alone because it does not allow predictions below about age 15, and the study function could not be used alone because its limited data base does not allow it to be a generally suitable site-index function.

2. A stand-level function that predicts the survival of all trees (eq. 4) and one that predicts the number of surviving trees 1 inch d.b.h. and larger from age 10 into the future by 1-year increments up to age 20 (eq. 5). For other species, a predictor for trees 1 inch d.b.h. and larger would be the only one needed. But, since longleaf has a grass-stage and trees can remain in this stage for many years, the first predictor is also necessary here. These functions are similar to a model presented by Hamilton (1974).

3. A mean total height predictor for each 1-inch d.b.h. class (eq. 6a). This function essentially predicts a proportion for each d.b.h. class that modifies stand mean dominant height. This function is similar to the model presented by Clutter and Belcher (1978).

4. A mean crown ratio predictor for each 1-inch d.b.h. class (eq. 7a). The underlying model is identical in form to the one in eq. 6a, but employs stem length (or height to the live crown base) as the dependent variable.

5. A function that predicts the number of trees in each 1-inch d.b.h. class (eq. 8a). This predictor utilizes the Weibull cumlative density function and estimates of the "b" and "c" parameters that are predicted by the stand variables age, dominant height, and trees per acre (eq. 8b, 8c). The "a" parameter was fixed at 0.55 because it is possible for any natural longleaf stand aged 10 through 20 years to have a tree in the first 1-inch d.b.h. class. The "b" and "c" parameter predictors were developed using the fitted values of "b" and "c" from a maximum-likelihood program developed for this purpose at the Southern Forest Experiment Station (Bailey 1974).

6. A set of tree volume-defining functions (Farrar 1981) for natural longleaf pines (eq. 10–15).

All functions were fitted using ordinary least squares multiple linear regression.

[1]Numbers and letters refer to equations presented in Appendix A.

RESULTS AND DISCUSSION

All of the above groups and component parts are presented in Appendix A, along with certain relative statistics for each critical component in Appendix B.

Also, the components have been inserted into a BASIC computer program (Appendix C) that allows generation of stand and stock tables for stands having the specifications and limits shown in table 1.

Appendix D shows example output from this program, stand and stock tables for ages 10, 15, 20; site index 70 and 80; and 300, 600, 900, 1,200, and 1,500 initial trees per acre (all trees, at age 10). By modifying a few program lines, the program can predict tables for other combinations of stand initial and final age, site index, and initial density within the above limits on minimum and maximum values given in table 1.

Several trends are evident upon inspection of these Appendices. Survival of all trees (TSO) is inversely related to initial density and is very good for the 10-year period studied. The poorest survival was 88 percent at age 20 for 1,500 initial trees per acre at age 10 and site index 70. Similarly, the poorest survival on site index 80 was 95 percent for otherwise similar conditions. These trends probably hold through age 20, but beyond that one would expect survival to become relatively poorer for site index 80 as competition becomes more intense on these better sites (Dell and others, 1979).

The modal d.b.h. class advances with age and the advance is most rapid for the lowest initial stand den-

Table 1.—*Specifications and limits of stand and stock tables*

Stand variable	Minimum value	Maximum value
Age (years)	10	20
Site index (feet) (MP50, index age = 50)	66	85
Initial number of trees per acre at age 10	300	1,500

sity. This effect is shown in figure 1 for initial densities of 300 and 1,500 trees on site index 70. Increasing site index accelerates the advance.

The number of trees per acre 1 inch d.b.h. and larger (TS1) is directly related to initial density, increases with age, and approaches and asymptote or declines slightly due to mortality in the higher densities (fig. 2). Increasing site index tends to increase the number of such trees at any age for any initial density.

The quadratic mean d.b.h. is negatively related to density, appears to approach an asymptote with density, and increases positively with age (fig. 3). The effect of site index is positive. The arithmetic mean d.b.h. response is similar but the values are, of course, smaller.

Total basal area per acre is positively related to initial density and age and appears to approach an asymptote with density (fig. 4). Over the 10-year period, the growth rate accelerated during the last 5 years for the lowest initial density and decelerated for the highest. The effect of site index is positive.

Mean crown ratio has a differential response to initial density and age (fig. 5). At the three lower densities it increases to a peak at middle ages and then declines with age, but at the two higher densities it generally declines slowly to the middle ages and then declines more rapidly. It appears to approach an

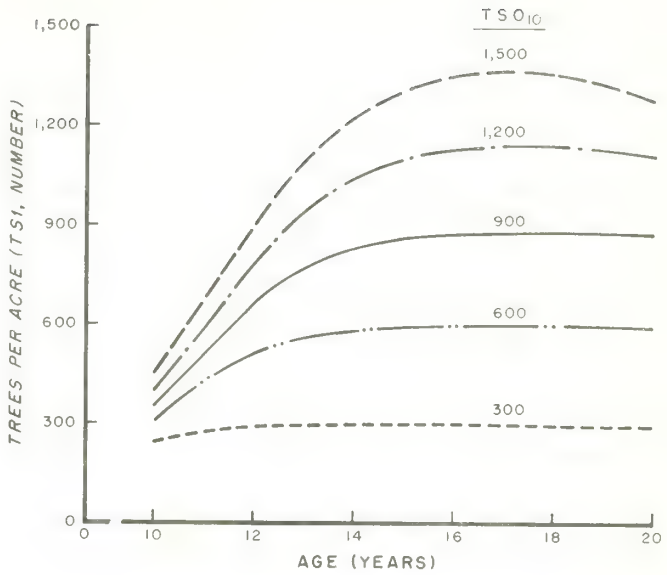

Figure 2.—*Predicted number of trees per acre (d.b.h. ≥ 0.6") at ages 10 through 20 years by initial stand density at age 10, site index 70.*

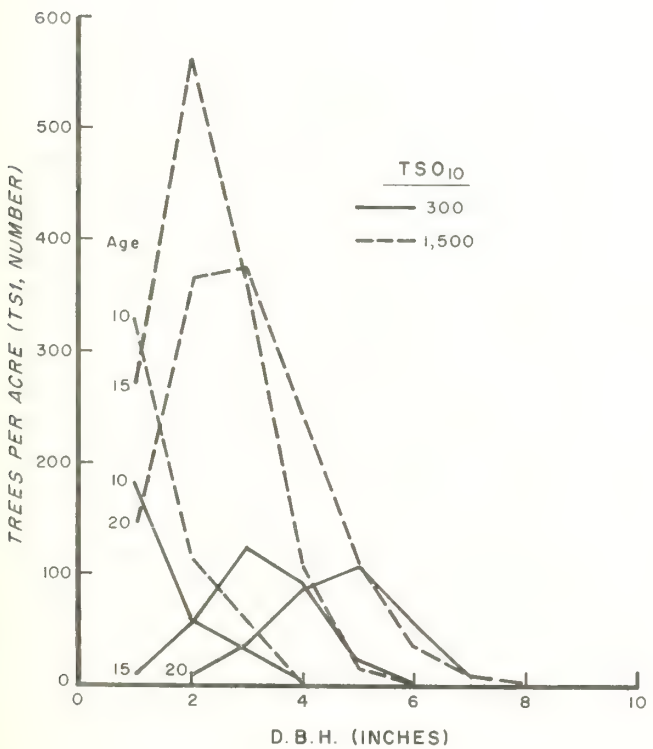

Figure 1.—*Predicted d.b.h. distributions for 300 (solid line) and 1,500 (dashed line) initial trees per acre at ages 10, 15, and 20 years, site index 70.*

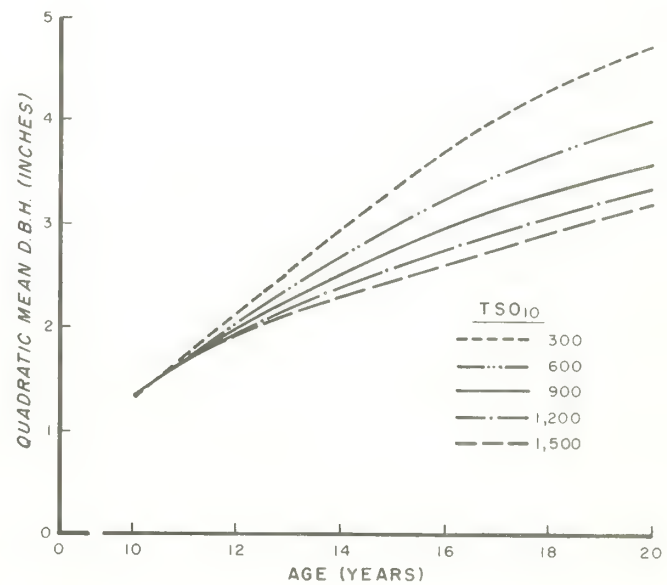

Figure 3.—*Predicted quadratic mean stand d.b.h. at ages 10 through 20 years by initial stand density at age 10, site index 70.*

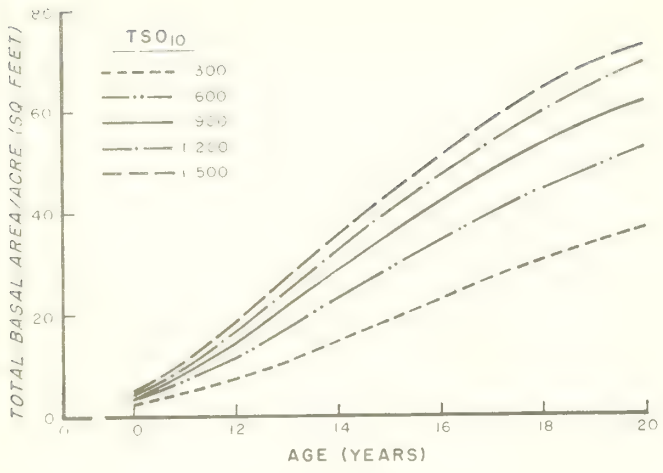

Figure 4.—*Predicted total stand basal area per acre at ages 10 through 20 years by initial stand density at age 10, site index 70.*

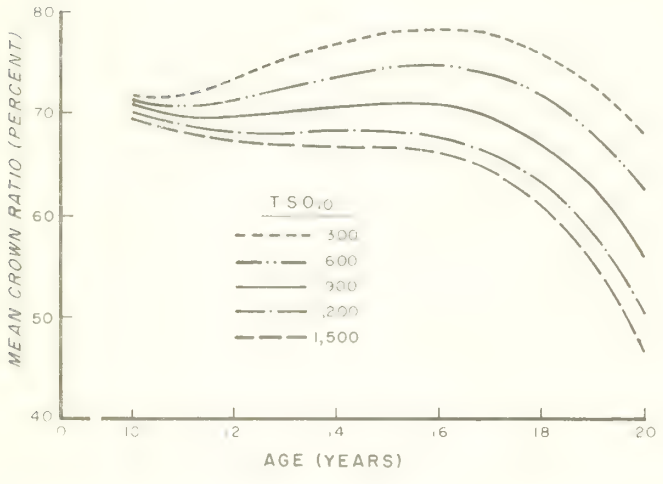

Figure 5.—*Predicted stand mean crown ratio percentage at ages 10 through 20 years by initial stand density at age 10, site index 70.*

asymptote with density. The general effect of increasing site index is to lower the crown ratio about 5 to 10 percentage points.

The total cubic-foot volume, inside bark, per acre (TVI) response is similar to the response of total basal area to age and initial density except that the growth rate appears to be accelerating for all densities over the 10-year period (fig. 6); probably because height growth is overcoming any reduction in basal area growth. The effect of site index is positive. The greater the age, site index, and initial density; the greater the total volume.

Merchantable cubic-foot volume, inside bark (VI43), is zero for all densities and both sites at age 10. By age 15, the 900-trees-per-acre density has the most volume on site index 70 (fig. 7) and 80. By age 20, volume has increased at an increasing rate such that the 1,200-trees/acre density has the most volume on site index 70 and the 1,500-trees/acre density on site index 80.

The merchantable mean annual volume (VI43) increments to age 20 are not striking, but the responses between age 10 and 20 are impressive, particularly for the last 5 years. For the period age 10 to age 20, the maximum predicted growth rates are 61.2 cubic feet/acre/year for site index 70 and 1,200 initial trees. For site index 80, the maximum is 101.5 cubic feet for 1,500 initial trees. Assuming 80 cubic feet/cord, these figures translate to 0.77 and 1.27 cords/acre/year. For the last 5 years (age 15 to 20), the maximum rates are 99.7 and 170.5 cubic feet/acre/year for site indices 70 and 80, respectively, and both for initial densities of 1,500 trees. These figures translate to 1.25 and 2.13 cords/acre/year.

If maximum stand merchantable cubic-foot volume production is desired, the results through age 20 do not suggest any practical benefit from having more than about 900 to 1,200 trees per acre at age 10 since these densities produced maximum or near-maximum volumes. However, if maximum total cubic-foot volume is desired, the highest initial density (1,500 TSO_{10}) is indicated. This information supports earlier conclusions (Farrar 1974) that to maximize early merchantable cubic-foot yields a density range of 500 to 1,000 established trees per acre appeared optimal and that, for this purpose, precommercial thinning should be considered only if stand density exceeded 1,000 crop seedlings at age 5 to 10 years. As the study continues, it may develop that a medium initial TSO density will maximize early sawtimber volumes also.

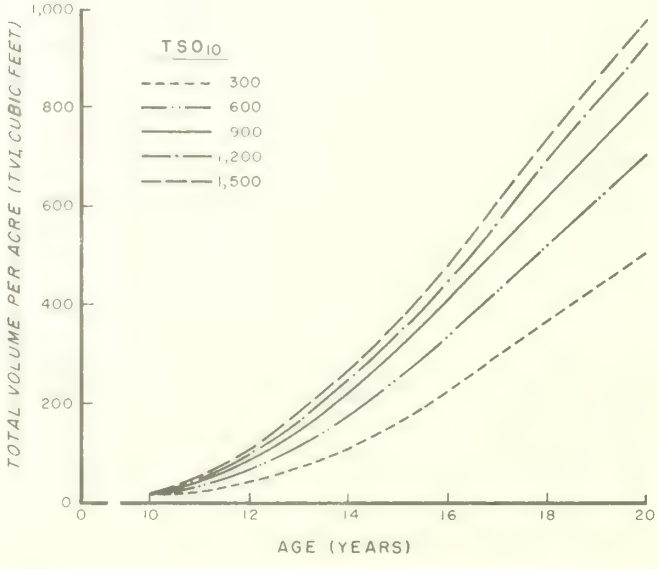

Figure 6.—*Predicted stand total cubic-foot volume, inside bark, per acre at ages 10 through 20 years by initial stand density at age 10, site index 70.*

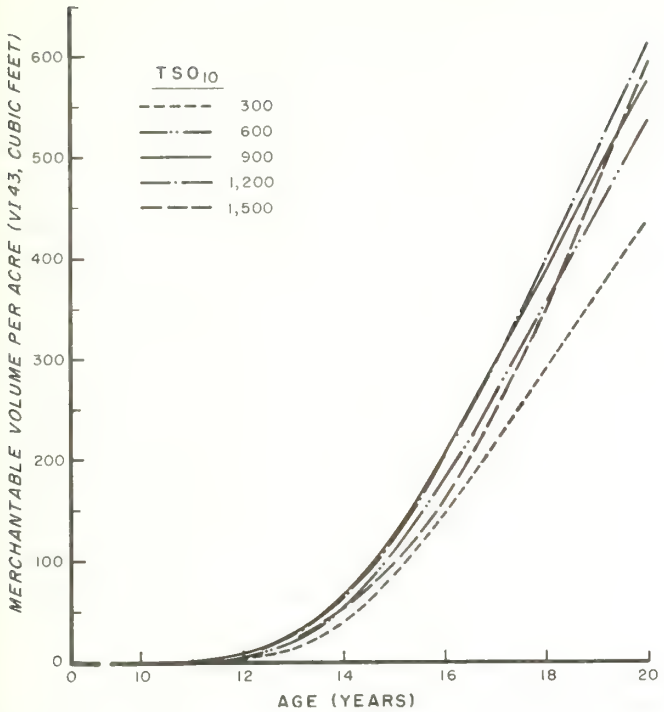

Figure 7.—*Predicted stand merchantable cubic-foot volume, inside bark, per acre at ages 10 through 20 years by initial stand density at age 10, site index 70.*

Preliminary results from this spacing study have been reported in two previous publications (Farrar 1974, 1979a). At the time of the first (Farrar 1974), neither the ages from seed (from increment borings) nor the site index were determinable. Age, although not specifically stated, was age from seed-tree removal which is 2 to 3 years younger than age from seed. Average site index was estimated in surrounding 60-year-old stands on similar soils to be about 70 feet. If the data in Farrar (1974) are updated to reflect the average age from seed (15 to 16 years) and the average site index (MP50) of about 80, the results are comparable to those presented herein.

In the second publication (Farrar 1979a) the ages are from seed but the average site index was estimated to be in the 70 class (about 75) by the site-index function in Farrar (1979b). If this site index is translated to MP50 site index, the value is about 80. Then, with due allowance for a different survival function in Farrar (1979a), the results are comparable. Since the results reported in these two previous publications were preliminary, they can be regarded to be superseded by the results reported herein.

To see, on the average, how well the prediction system reproduces certain observed stand values for the 15 plots at nominal ages 10, 15, and 20 years; the mean difference ($\bar{d}$), percent mean difference ($\overline{\%d}$), root mean square difference (RMSd), and root mean square percent difference (RMS%d) were calculated and are presented in table 2. The latter two measures are comparable to absolute (algebraic sign ignored) values. The "observed" values for each plot at each age were determined by the procedures given by Farrar (1979b) for plot inventory summary. Briefly, observed volumes were obtained by fitting a total height function in terms of d.b.h. for each plot, using this function in conjunction with the tree volume formulae presented herein to estimate a volume for every tree on the plot, and summing tree volumes to obtain plot volumes. Observed trees per acre and basal area were the actual values per plot. Observed ages were the actual mean age at nominal ages 10, 15, and 20 years for each plot.

Predicted plot values were obtained by using the following inputs to the appended program:

a. Site index (MP50) observed at nominal age 20 on each plot.

b. The actual plot age at nominal age 20 and backdated 5 and 10 years to obtain estimates at nominal ages 15 and 10.

c. The number of trees at the age in b., above, were obtained via the survival function (eq. 4) by starting with the treatment densities at the backdated age at nominal age 10 and projecting forward 5 and 10 years.

The results of this exercise (table 2) suggest that the predictions improve with time and that all are within usable limits. At ages 15 and 20, they are comparable to results from other studies of natural even-aged southern pine growth and production (Farrar 1979b, Murphy and Sternitzke 1979, Murphy and Beltz 1981). At age 10, the percentage differences are comparatively large but small in real terms. This is not surprising because at this young age there is considerable variability in the stand taller than breast height. Later, as more of the stand passes the breast-height threshold, stand traits become more predictable.

If stand and stock tables are desired for conditions other than those shown in the Appendix, but within the study limits, the program (Appendix B) can be modified to provide output for any integer age between 10 and 20 years, any site index in the 70 and 80 classes, and any initial integer number of trees per acre between 300 and 1,500. The desired input values are specified in line 80, and lines 120, 130, and 140 are modified as needed. For example, if annual output is desired for site index 75 at ages 13 through 17 for 750 initial trees per acre at age 13, the input would be *75, 75, 13, 17, 750, 750* and line 140 would be altered to read: *FOR A =A1 to A2 STEP 1*.

If for some reason the MP50 site-index function is not deemed appropriate, but the rest of the process is considered suitable, some other site-index function thought to be more appropriate can be solved as a dominant-height function at age 20 and substituted in line 280.

Table 2.—*Goodness of fit" statistics for the stand and stock table prediction system*[1]

Predicted value	n	$\overline{Obs}$	$\bar{d}$	$\overline{\%d}$	RMSd	RMS%d
			Age 10			
TS1 (no.)	15	349.7	−5.07	5.2	63.73	24.4
B (ft^2)	15	3.2	0.08	6.4	0.76	26.1
TVO (ft^3)	15	28.6	0.05	5.4	7.00	27.1
TVI (ft^3)	15	14.8	0.15	5.9	3.93	28.7
VO43 (ft^3)	..	.....	.....	.....	.....	.....
VI43 (ft^3)	..	.....	.....	.....	.....	.....
			Age 15			
TS1	15	830.7	30.13	0.04	74.66	7.4
B	15	43.1	−0.49	−0.8	4.31	10.3
TVO	15	690.7	−23.85	−4.3	83.09	12.3
TVI	15	453.3	−15.66	−3.2	55.73	12.6
VO43	15	347.3	−12.55	−3.0	54.05	16.2
VI43	15	233.3	−6.7	−2.3	36.72	16.5
			Age 20			
TS1	15	832.0	30.20	3.8	61.26	6.4
B	15	68.0	−0.71	−0.6	4.51	6.9
TVO	15	1454.8	−4.13	0.1	115.09	8.6
TVI	15	1012.0	−4.43	−0.01	81.71	8.8
VO43	15	1088.1	−23.26	−1.4	102.84	9.8
VI43	15	767.6	−16.4	−0.4	72.97	9.8

[1]n = number of observations
y_i = ith observed value
$\hat{y}_i$ = ith predicted value

$$\overline{Obs} = \left(\sum_{i=1}^{n} (y_i)\right)/n$$

$$\bar{d} = \left(\sum_{i=1}^{n} (\hat{y}_i - y_i)\right)/n$$

$$\overline{\%d} = \left(\sum_{i=1}^{n} ((\hat{y}_i - y_i)/y_i)/n\right)*(100)$$

$$RMSd = \sqrt{\left(\sum_{i=1}^{n} (\hat{y}_i - y_i)^2\right)/n}$$

$$RMS\%d = \sqrt{\left(\sum_{i=1}^{n} ((\hat{y}_i - y_i)/y_i)^2\right)/n}*(100)$$

..... = no data observed or predicted

Besides providing estimates of the production in 10- to 20-year-old longleaf stands, this system can provide entry to other growth and production prediction systems that usually start at about age 20. For example, assume that we have a longleaf stand at age 10 that has 1,200 trees per acre and a site index of 70 feet (MP50) and we would like to estimate its volume at age 25. At age 20, Appendix C shows this stand should have a dominant height of 36.4 feet, 68.9 square feet of basal area (B), and the following cubic-foot volumes per acre: total, inside bark (TVI) = 930; merchantable, inside bark (VI43) = 612. The indicated merchantable periodic annual increment from age 15 to 20 is 97.8 cubic feet. Using the functions in a recently published system for volume growth and production prediction for thinned natural longleaf (Farrar 1979b) that uses some of the same tree volume-defining functions but a different site-index function, the following values are obtained at age 20. The 36.4-foot dominant height translates to a site index (Farrar 1979b) of 65.6 feet and the cubic-foot volume estimates are TVI = 914 and VI43 = 661. These are within ±2 to 8 percent of the above values. At age 25, the predictions from the functions in Farrar (1979b) are B = 99 square feet/acre, TVI = 1,639, and VI43 = 1,390.

The estimated average annual growth from age 20 to 25 is 6 square feet of basal area and 145.8 cubic feet of merchantable volume or 1.82 cords. The merchantable mean annual increments at ages 20 and 25 (33.1 and 55.6 cubic feet) suggest that the periodic annual cubic-foot volume increment has not peaked for this stand by age 20.

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Appendix A—System Predictor Groups and Components

(1) $H_{20} = (S_{50})(10)^{\{g(20)-g(50)\}}$

(2) $S_{20} = (H_{20})[\exp\{f(20) - f(20)\}] = H_{20}$

(3a) $HD1_A = (S_{20})[\exp\{f(A) - f(20)\}]$

where: H_20 = mean height of dominant stand at age 20, predicted from MP50 dominant-height function (Farrar 1973), feet

S_{50} = site index, index age 50 years, feet ($65 < S_{50} \leq 85$)

(3b) $g(A) = -11.870(1/A) + 1263.79(1/A)^3 - 12409.5(1/A)^4$ (Farrar 1973)

S_{20} = site index, index age 20 years, feet

(3c) $f(A) = 51.5672(1/A) - 976.490(1/A)^2 + 3836.84(1/A)^3$ [1]

[1]From the fitted function:

(3d) $\ln(HD1_A = 3.08908 + 51.5672(1/A) - 976.490(1/A)^2 + 3836.84(1/A)^3$

A = given age, years

$HD1_A$ = predicted mean height of dominant stand at age A, feet (A, here, = 10, 11, - - - 19, or 20).

Total tree frequencies per stand at age A

The number of surviving trees per acre is predicted in an iterative fashion by a modified form of a function presented by Hamilton (1974).

(4) $TSO_{A+1} = TSO_A/[0.99999 + \exp\{-20.964 + 1.1808(A) - 0.25569(HD1_A) + 0.0031657(TSO_A)\}]$

where: TSO_A = number of surviving trees per acre (all) at age A years

TSO_{A+1} = number of surviving trees per acre (all) at age (A + 1) years. Note that $TSO_A + 1$ becomes TSO_A for each new iteration of this function. Minimum A = 10, maximum (A + 1) = 20, minimum TSO_{10} = 300, maximum TSO_{10} = 1,500.

The number of surviving trees in the 1-inch class and larger is predicted by:

(5) $TS1_A = TSO_A/[0.99999 + \exp\{3.7052 - 2.5068(HD1_A/A) - 94.772(HD1_A/TSO_A)\}]$

where: $TS1_A$ = number of surviving trees per acre (d.b.h. > = 0.6 inches) at age A years.

Mean height for a given d.b.h. class at age A

(6a) $H1_{iA} = (HD1_A)[\exp\{b_{0A} + b_{1A}(1/D_i)\}]$

where: $H1_{iA}$ = predicted mean tree total height for the ith 1-inch d.b.h. class at age A, feet

(6b) $b_{0A} = 0.23727 + 5.9139/HD1_A$

(6c) $b_{1A} = -0.19070 - 0.012645(TS1_A/A) - 0.11953(HD1_A) + 0.0010798(TS1_A) + 0.0016258(HD1_A)^2$

D_i = midpoint of the ith 1 inch d.b.h. class, inches.

Mean crown ratio for a given d.b.h. class at age A

(7a) $CR_{iA} = \{(H1_{iA} - SL_{iA})/H1_{iA}\}(100)$

where: CR_{iA} = mean crown ratio for the ith 1-inch d.b.h. class at age A, percent

(7b) $SL_{iA} = (HD1_A)[\exp\{c_{0A} + c_{1A}(1/D_i)\}]$

where: SL_{iA} = predicted mean tree height to the live crown base for the ith 1-inch d.b.h. class at age A, feet

(7c) $c_{0A} = 3.4392 - 0.54950(A) + 0.045001(HD1) + 0.00057003(A^3) + 0.000000048139(A^3)(TS1_A)$

(7d) $c_{1A} = -0.53734 - 0.0025185(A^2) + 0.000018202(A)(TS1_A)$.

Tree frequencies by d.b.h. class at age A

(8a) $TS1_{iA} = N2_A - N1_A$

where: $N1_A = (TS1_A)[1 - \exp\{-((D_i - a)/b_A)^{cA}\}]$

$N2_A = (TS1_A)[1 - \exp\{-((D_i + 1 - a)/b_A)^{cA}\}]$

and

$TS1_{iA}$ = number of surviving trees per acre (d.b.h. > = 0.6 inch) in the ith 1-inch d.b.h. class at age A years.

$a = 0.55$

(8b) $b_A = -0.78012 - 0.000084899(HD1_A)(TS1_A) + 0.17355(HD1_A) + 0.00087836(TS1_A) - 0.0000013083(HD1_A)^2(TS1_A) + 0.0000000010321(HD1_A)^2(TS1_A)^2$

(8c) $c_A = 0.80699 - 0.00025619(HD1_A)(TS1_A) + 0.00000010200(HD1_A)(TS1_A)^2 + 0.16045(HD1_A) + 0.00096973(TS1_A)$.

Basal area per acre by d.b.h. class at age A

(9) $B_{iA} = (TS1_{iA})(\pi/576)(D_i)^2$

where: B_{iA} = basal area per acre in the ith 1-inch d.b.h. class at age A, square feet.

Mean tree volume for a given d.b.h. class at age A

(10) $TVI_{iA} = 0.00535 + 0.0021971(D_i)^2(H1_{iA})$

where: TVI_{iA} = tree volume in cubic feet, inside bark, from a 0.2-foot stump to a zero-inch top d.o.b., d.b.h. > = 0.6 inch

(11) $TVO_{iA} = (TVI_{iA})\{1 + (10^{b0})(TVI_{iA})^{b1}\}$

where: TVO_{iA} = same specifications as TVI_{iA} except outside bark

$b_0 = -0.30925$

$b_1 = -0.21895$

(12) $VI42_{iA} = (TVI_{iA})/\{1 + (10^{b02})(TVI_{iA})^{b12}\}$

where: $VI42_{iA}$ = tree merchantable volume in cubic feet, inside bark, from a 0.2-foot stump to a 2-inch top d.o.b., d.b.h. > = 3.6 inches

$b_{02} = -1.2415$

$b_{12} = -1.2107$

(13) $VO42_{iA} = (VI42_{iA})\{1 + (10^{b0})(VI42_{iA})^{b1}\}$

where: $VO42_{iA}$ = same specifications as $VI42_{iA}$ except outside bark

(14) $VI43_{iA} = (TVI_{iA})/\{1 + (10^{b03})(TVI_{iA})^{b13}\}$

where: $VI43_{iA}$ = tree merchantable volume in cubic feet, inside bark, from a 0.2-foot

stump to a 3-inch top d.o.b., d.b.h. > = 3.6 inches

$b_{03} = -0.54930$

$b_{13} = -1.3024$

(15) $VO43_{iA} = (VI43_{iA})\{1 + (10^{b0})(VI43_{iA})^{b1}\}$

where: $VO43_{iA}$ = same specifications as $VI43_{iA}$ except outside bark.

Per acre tabular values

(16) $TS1_A = \sum_{i=1}^{n} (TS1_{iA})$

(17) $B_A = \sum_{i=1}^{n} (B_{iA})$

(18) $Volume_A = \sum_{i=1}^{n} \{(Volume_{iA})(TS1_{iA})\}$

where $Volume_A$ = a total volume and $Volume_{iA}$ = volume per tree in the ith 1-inch d.b.h. class, for any volume function

(19) $\overline{D}_A = \{\sum_{i=1}^{n} (D_i)(TS1_{iA})\}/TS1_A$

where $\overline{D}_A$ = arithmetic mean d.b.h.

(20) $\overline{D}_Q = \sqrt{B_A/\{(\pi/576)(TS1_A)\}}$

where $\overline{D}_Q$ = quadratic mean d.b.h.

(21) % Survival = $TS0_A/TS0_{10}$

(22) $\overline{CR}_A = \{\sum_{i=1}^{n} (CR_{iA})(TS1_{iA})\}/TS1_A$

where $\overline{CR}_A$ = arithmetic mean crown ratio percentage.

Appendix B—Coefficient of Determination and Standard Error of Regression for Fitted Functions

Equation no.	n	R^2 or r^2	$s_{y \cdot x}$
(3d)	90	0.987*	0.063*
(4)	150	0.315*	2.653*
(5)	90	0.735*	2.211*
(6b)	90	0.811	0.094
(6c)	90	0.727	0.214
(7c)	90	0.482	0.280
(7d)	90	0.204	0.397
(8b)	90	0.984	0.148
(8c)	90	0.846	0.327

*In logarithmic form, from regression where y was transformed to ln (y).

Appendix C—BASIC Program to Generate Predicted Stand and Stock Tables for Young Natural Longleaf Pine

```
10   REM THIS PROGRAM "LLS#80" GENERATES STAND AND STOCK TABLES FOR YOUNG
     NATURAL LONGLEAF PINE STANDS HAVING INITIAL AND FINAL AGES BETWEEN 10 AND
20   REM 80 YEARS, SITE INDEX (INDEX AGE 50 YEARS, MISC. PUBL. 50) OF 65 TO 85
     FEET, AND INITIAL DENSITIES OF 300 TO 1500 TREES PER ACRE AT INITIAL AGE.
30   OPTION BASE 1
40   DATUM# 15 #
50   DIMEQ## 9,5,D
70   REAL N1,N2,H1(30),T0(30)
80   INPUT "S1,S2,A1,A2,T1,T2 ?",S1,S2,A1,A2,T1,T2
81   PRINT LIN(5)
90   IMAGE "YIELDS GIVEN TSO (# OF TREES PER ACRE AT DESIRED INITIAL AGE) WITH T
     SURVIVAL--"
100  PRINT USING 90
101  PRINT LIN(3)
110  N99=1
120  FOR S=S1 TO S2 STEP 10
130  FOR T0=T1 TO T2 STEP 300
140  FOR A=A1 TO A2 STEP 1
150  IF N99>=3 THEN 180
160  IF A1<10 THEN 270
170  GOTO 200
171  WAIT 500
172  PRINT LIN(12)
180  IMAGE 40X,"CU. FT. VOL. ABOVE 0.2 FT. STUMP"
190  PRINT USING 180
191  GOTO 220
192  PRINT LIN(12)
200  IMAGE 40X,"CU. FT. VOL. ABOVE 0.2 FT. STUMP"
210  PRINT USING 200
211  IMAGE 40X,"ALL TREES  +  4-INCH CLASS & UP"
212  PRINT USING 211
220  IMAGE 6X,"AV.",4X," STEMS",14X,9("*"),"FOR O.B.  TOPS OF----",9("*")
230  PRINT USING 220
240  IMAGE 1X,"TSO SI AGE  D+C DBH PER  BASAL CR  AV. 0   INCHES   +   2 INCHES
  +   4 INCHES"
250  PRINT USING 240
260  IMAGE 1X,"OT.",5X,"ACRE AREA",6X,"HT. o.b.   1.b.  +  o.b.   1.b. +   o.b.
  1.b."
261  PRINT USING 260
262  IMAGE 80("-")
263  PRINT USING 262
270  N99=N99+1
271  IF N99=4 THEN N99=2
280  H20=S*.520219437307
281  T0=A1-1
290  FOR I=A1 TO A2 STEP 1
300  H1(I)=H20*EXP(51.5672-976.49/I^2+3836.84/I^3-.61674)
310  T0(I+1)=T0(I)*(.99999+EXP(-20.964+1.1808*I-.25569*H1(I)+.0031657*T0(I)))
320  NEXT I
330  I=A
340  T11=T0(I)*(.99999+EXP(3.7052-2.5068*(H1(I)/I)-94.772*(H1(I)/T0(I))))
350  A4=.55
360  B=-.7201+3.4699E-5*H1(I)*T11+.17355*H1(I)+8.7836E-4*T11-1.3083E-6*H1(I)^2*
     T11+1.0221E-5*H1(I)^2*T11^2
```

```
370  C=.80699-2.5619E-4*H1(I)*T11+1.02E-7*H1(I)*T11^2+.16049*H1(I)+9.6973E-4*T11
380  S11=0
390  D13=0
400  T111=0
410  T121=0
420  T123=0
430  V111=0
440  V121=0
450  V123=0
460  V124=0
461  Crpp=0
470  PRINT USING "DDDD,1X,DD,1X,DD,2X,DD.D";T0,S,A,H1(A)
471  PRINT LIN(1)
480  D=1
490  D11=1.5
500  IF D=2 THEN D11=1.5
510  N1=T11*(1-EXP(-((D11-A4)/B)^C))
520  N2=T11*(1-EXP(-((D11+1-A4)/B)^C))
530  T112=N2-N1
540  IF D=1 THEN T112=N1
550  T112=PROUND(T112,0)
560  B0=.23727+5.9139/H1(A)
570  B1=-.19070-.012645*T11/A-.11953*H1(A)+.0010798*T11+.0016253*H1(A)^2
580  H10=H1(A)*EXP(B0+B1/D)
581  C0=3.7392-.54950*I+.045001*H1(I)+5.7003E-4*I^3+4.8139E-8*I^3*T11
582  C1=-.53734-.00251857*I^2+1.8202E-5*I*T11
583  S1=H1(I)*EXP(C0+C1/D)
584  Cr=(H10-S1)/H10*100
586  IF Cr<=5 THEN Cr=10
590  B00=D^2*(3.14159254/576)*T112
600  T00=.00535+.0021971*D^2*H10
610  T012=T00*T112
620  T01=T00*(1+10^(-.30925)*T00^(-.21895))
630  T013=T01*T112
640  T121=T121+T012
650  T123=T123+T013
660  S11=S11+B00
670  D12=D*T112
680  D13=D13+D12
681  Crpc=Cr*T112
682  Crpp=Crpp+Crpc
683  Cr=PROUND(Cr,-1)
690  T111=T111+T112
700  IF D=1 THEN 890
710  IF T112<.50000000001 THEN 910
720  IF D<4 THEN 890
730  V14=T00/(1+10^(-1.2415)*T00^(-1.2107))
740  V112=V14*T112
741  V112=PROUND(V112,-1)
750  V15=V14*(1+10^(-.30925)*V14^(-.21895))
760  V113=V15*T112
761  V113=PROUND(V113,-1)
770  V16=T00/(1+10^(-.5493)*T00^(-1.3024))
780  V114=V16*T112
781  V114=PROUND(V114,-1)
790  V17=V16*(1+10^(-.30925)*V16^(-.21895))
800  V115=V17*T112
801  V115=PROUND(V115,-1)
810  V111=V111+V112
820  V121=V121+V113
```

```
830  V123=V123+V114
840  V124=V124+V115
850  PRINT USING "17X,DD,2X,DDD,1X,DD.D,2(2X,DD),2X,DDD.D,2X,DDD.D,2(2X,DDD.D,2X
,DDD.D)";D,T112,B00,Cr,H10,T013,T012,V113,V112,V115,V114
860  D=D+1
861  D11=D11+1
870  IF D<11 THEN 500
880  GOTO 910
890  PRINT USING "17X,DD,2X,DDD,1X,DD.D,2(2X,DD),2X,DDD.D,2X,DDD.D";D,T112,B00,C
r,H10,T013,T012
900  GOTO 860
910  D33=D13/T11
920  D44=SQR(S11/(.005454*T11))
930  R1=T0(I)
940  R2=T0(A1)
950  S55=R1/R2*100
951  Barcr=Crpp/T11
960  IMAGE 20X,"_____ _____          ______ ______ ______ ______ ______ ______"
970  PRINT USING 960
972  IF D<5 THEN 1000
980  PRINT USING "20X,DDDD,2X,DD.D,9X,DDDD.D,1X,DDDD.D,1X,DDDD.D,1X,DDDD.D,1X,DD
DD.D,1X,DDDD.D";T111,S11,T123,T121,V121,V111,V124,V123
981  PRINT LIN(1)
990  GOTO 1030
1000 PRINT USING "20X,DDDD,2X,DD.D,9X,DDD.D,1X,DDD.D";T111,S11,T123,T121
1001 PRINT LIN(1)
1030 PRINT USING "17A,D.DD,1X,18A,D.DD";"ARITH. MEAN DBH =",D33," QUADR. MEAN DB
H =",D44
1035 PRINT USING "17A,D.DD,2(1X,3A,D.DD/";"WEIBULL PARAM: A=",A4,"B=",B,"C=",C
1040 PRINT USING "12A,1X,DDD.D,5X,19A,1X,DDD.D";"SURVIVAL %=",S55,"MEAN CROWN RA
TIO %=",Barcr
1041 PRINT LIN(6)
1050 NEXT A
1051 PAUSE
1060 NEXT T0
1070 NEXT S
1090 END
```

Appendix D—Predicted Stand and Stock Tables for Young Natural Longleaf Pine at Various Initial Densities, Site Indices, and Ages

YIELDS GIVEN TSO (# OF TREES PER ACRE AT DESIRED INITIAL AGE) WITH TYPICAL SURVIVAL--

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0 2 FOOT STUMP---- ALL TREES 0 INCHES O.B.	I.B.	* FOR 0.B. TOPS OF 4-INCH CLASS AND GREATER 2 INCHES O.B.	I.B.	* 3 INCHES O.B.	I.B.
300	70	10	9.1											
				1	183	1.0	70.2	6.7	7.9	3.7				
				2	59	1.3	76.1	12.2	11.9	6.6				
				3	1	.0	77.8	14.9	.5	.3				
					243	2.3			20.3	10.6				

ARITH. MEAN DBH = 1.3 QUADRATIC MEAN DBH =1.33 WEIBULL PARAMETERS A = .55 B = .80 C =1.99

% SURVIVAL= 100.0 MEAN CROWN RATIO = 71.8

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES 0 INCHES O.B.	I.B.	* FOR 0.B. TOPS OF 4-INCH CLASS AND GREATER 2 INCHES O.B.	I.B.	* 3 INCHES O.B.	I.B.
300	70	15	24.9											
				1	6	.0	56.1	5.0	.2	.1				
				2	57	1.2	74.2	14.1	13.0	7.4				
				3	123	6.0	78.4	19.9	78.6	49.2				
				4	92	8.0	80.2	23.7	116.6	77.2	109.4	72.1	88.1	57.0
				5	21	2.9	81.3	26.3	44.3	30.5	42.8	29.4	38.1	26.0
				6	1	.2	81.9	28.2	3.2	2.2	3.1	2.2	2.9	2.0
					300	18.4			255.9	166.6	155.3	103.7	129.1	85.0

ARITH. MEAN DBH = 3.2 QUADRATIC MEAN DBH =3.35 WEIBULL PARAMETERS A = .55 B =2.98 C =3.40

% SURVIVAL= 100.0 MEAN CROWN RATIO = 78.0

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ********FOR O.B. TOPS OF---******** 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B	3 INCHES I.B
300	70	20	36.4													
				1	0	0.0	40.5	5.7	0.0	0.0						
				2	7	.2	60.4	17.6	1.9	1.1						
				3	35	1.7	65.5	25.6	28.1	17.9						
				4	87	7.6	67.8	30.9	140.7	95.0		134.3	90.4		114.3	75.9
				5	107	14.6	69.1	34.6	290.8	203.9		283.9	198.7		261.2	181.8
				6	54	10.6	69.9	37.3	221.4	159.6		218.2	157.2		208.0	149.3
				7	8	2.1	70.5	39.4	46.1	33.9		45.6	33.6		44.3	32.5
					298	36.8			729.1	511.5		682.8	479.9		627.8	439.5

ARITH. MEAN DBH = 4.6 QUADRATIC MEAN DBH =4.75 WEIBULL PARAMETERS A = .55 B =4.48 C =4.48

% SURVIVAL= 99.6 MEAN CROWN RATIO = 68.0

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES * 4-INCH CLASS AND GREATER ********FOR O.B. TOPS OF---******** 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B	3 INCHES I.B
600	70	10	9.1													
				1	226	1.2	69.5	6.7	9.7	4.5						
				2	75	1.6	75.8	12.1	15.1	8.4						
				3	1	.0	77.6	14.8	.5	.3						
					302	2.9			25.3	13.2						

ARITH MEAN DBH = 1.3 QUADRATIC MEAN DBH =1.33 WEIBULL PARAMETERS A = .55 B = .80 C =1.94

% SURVIVAL= 100.0 MEAN CROWN RATIO = 71.2

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- FOR O.B. TOPS OF---- 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B.
600	70	15	24.9													
				1	49	.3	53.5	5.3	1.8	.8						
				2	189	4.1	72.8	14.6	44.5	25.2						
				3	214	10.5	77.3	20.4	139.7	87.5						
				4	110	9.6	79.2	24.1	141.7	93.9		133.1	87.8		107.6	69.8
				5	27	3.7	80.3	26.7	57.7	39.7		55.8	38.4		49.8	34.0
				6	3	.6	81.0	28.6	9.6	6.8		9.4	6.7		8.8	6.2
					592	28.8			394.9	254.0		198.3	132.9		166.2	110.0

ARITH. MEAN DBH = 2.8 QUADRATIC MEAN DBH =2.98 WEIBULL PARAMETERS A = .55 B =2.55 C =2.49

% SURVIVAL= 99.9 MEAN CROWN RATIO = 74.4

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES * 4-INCH CLASS AND GREATER FOR O.B. TOPS OF---- 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B	*	3 INCHES O.B	3 INCHES I.B
600	70	20	36.4													
				1	10	.1	34.9	6.5	.4	.2						
				2	72	1.6	56.2	18.8	21.2	12.3						
				3	157	7.7	61.7	26.8	131.2	84.0						
				4	182	15.9	64.1	32.0	303.5	205.4		290.2	195.7		248.4	165.5
				5	120	16.4	65.5	35.5	334.3	234.8		326.5	229.0		301.3	210.1
				6	43	8.4	66.4	38.1	180.0	129.9		177.5	128.0		169.3	121.8
				7	8	2.1	67.0	40.1	46.9	34.6		46.5	34.3		45.1	33.2
				8	1	.3	67.5	41.7	7.8	5.9		7.8	5.8		7.6	5.7
					593	52.5			1025.3	707.0		848.5	592.8		771.7	536.3

ARITH. MEAN DBH = 3.8 QUADRATIC MEAN DBH =4.03 WEIBULL PARAMETERS A = .55 B =3.68 C =3.00

% SURVIVAL= 99.1 MEAN CROWN RATIO = 62.4

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES FOR O.B. 0 INCHES O.B.	0 INCHES I.B.	4-INCH CLASS AND GREATER TOPS OF---- 2 INCHES O.B.	2 INCHES I.B.	3 INCHES O.B.	3 INCHES I.B.
900	70	10	9.1											
				1	258	1.4	68.9	6.6	11.1	5.1				
				2	87	1.9	75.5	12.1	17.4	9.7				
				3	2	.1	77.4	14.8	1.0	.6				
					347	3.4			29.4	15.4				

ARITH. MEAN DBH = 1.3 QUADRATIC MEAN DBH =1.34 WEIBULL PARAMETERS A = .55 B = .81 C =1.91

% SURVIVAL= 100.0 MEAN CROWN RATIO = 70.8

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES FOR O.B. 0 INCHES O.B.	0 INCHES I.B.	4-INCH CLASS AND GREATER TOPS OF---- 2 INCHES O.B.	2 INCHES I.B.	3 INCHES O.B.	3 INCHES I.B.
900	70	15	24.9											
				1	137	.7	51.0	5.7	5.3	2.4				
				2	315	6.9	71.5	15.0	76.2	43.3				
				3	255	12.5	76.2	20.8	169.7	106.4				
				4	115	10.0	78.3	24.5	150.3	99.8	141.4	93.4	114.6	74 5
				5	31	4.2	79.4	27.0	67.0	46.2	64.9	44.6	58.0	39.6
				6	5	1.0	80.1	28.9	16.1	11.4	15.8	11.2	14.8	10.4
				7	1	.3	80.6	30.2	4.5	3.3	4.4	3.2	4.3	3.1
					859	35.6			489.0	312.9	226.5	152.4	191.7	127.6

ARITH. MEAN DBH = 2.5 QUADRATIC MEAN DBH =2.76 WEIBULL PARAMETERS A = .55 B =2.25 C =2.03

% SURVIVAL= 99.8 MEAN CROWN RATIO = 70.9

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ****FOR 0.B. TOPS OF---- 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B.
900	70	20	36.4													
				1	62	.3	29.2	7.4	2.9	1.3						
				2	198	4.3	51.8	20.0	61.5	35.9						
				3	248	12.2	57.6	27.9	215.2	138.2						
				4	197	17.2	60.3	33.0	338.2	229.3		323.8	218.9		278.7	186.2
				5	109	14.9	61.8	36.4	310.8	218.7		303.8	213.4		280.9	196.3
				6	43	8.4	62.7	38.9	183.5	132.6		181.0	130.7		172.9	124.5
				7	12	3.2	63.4	40.8	71.5	52.8		70.9	52.3		68.9	50.7
				8	3	1.0	63.9	42.3	23.8	17.9		23.6	17.7		23.2	17.4
					872	61.6			1207.3	826.7		903.1	633.0		824.6	575.1

ARITH. MEAN DBH = 3.3 QUADRATIC MEAN DBH =3.60 WEIBULL PARAMETERS A = .55 B =3.14 C =2.18

% SURVIVAL= 97.7 MEAN CROWN RATIO = 55.8

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES * 4-INCH CLASS AND GREATER ****FOR 0.B. TOPS OF---- 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B.
1200	70	10	9.1													
				1	293	1.6	68.2	6.5	12.5	5.8						
				2	101	2.2	75.3	12.0	20.1	11.2						
				3	2	.1	77.2	14.7	1.0	.6						
					396	3.9			33.6	17.6						

ARITH. MEAN DBH = 1.3 QUADRATIC MEAN DBH =1.34 WEIBULL PARAMETERS A = .55 B = .81 C =1.87

% SURVIVAL= 100.0 MEAN CROWN RATIO = 70.1

TSD(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ***FOR O.B. TOPS OF---- 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B.
1200	70	15	24.9													
				1	221	1.2	48.6	6.0	8.9	4.1						
				2	428	9.3	70.2	15.5	106.1	60.5						
				3	297	14.6	75.2	21.2	201.0	126.3						
				4	116	10.1	77.4	24.9	153.5	102.0		144.6	95.6		117.6	76.5
				5	32	3.8	78.6	27.3	61.1	42.2		59.2	40.8		53.0	36.2
				6	5	1.0	79.3	29.1	16.3	11.5		16.0	11.3		14.9	10.5
					1099	40.0			546.9	346.7		219.8	147.7		185.5	123.2

ARITH. MEAN DBH = 3.0 QUADRATIC MEAN DBH =3.59 WEIBULL PARAMETERS A = .55 B =2.06 C =1.92

% SURVIVAL= 99.4 MEAN CROWN RATIO = 68.2

TSD(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	-----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES * 4-INCH CLASS AND GREATER ***FOR O.B. TOPS OF---- 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B.
1200	70	20	36.4													
				1	124	.7	23.9	8.2	6.1	2.9						
				2	300	6.5	47.7	21.1	97.6	57.3						
				3	190	15.1	53.9	28.9	276.2	177.8						
				4	213	18.6	56.7	33.9	374.8	254.6		359.4	243.4		310.7	208.1
				5	108	14.7	58.1	37.2	314.1	221.3		307.2	216.1		284.7	199.2
				6	42	8.2	59.3	39.6	182.2	131.9		179.8	130.0		172.0	124.0
				7	16	3.5	60.0	41.5	78.6	58.1		77.9	57.6		75.8	55.8
				8	3	1.0	60.5	42.9	24.5	18.1		23.9	18.0		23.5	17.6
				9	1	.4	60.9	44.0	10.3	7.8		10.2	7.8		10.1	7.7
					1117	68.9			1364.1	929.8		958.4	672.9		876.8	612.4

ARITH. MEAN DBH = 3.1 QUADRATIC MEAN DBH =3.37 WEIBULL PARAMETERS A = .55 B =2.84 C =1.95

% SURVIVAL= 94.5 MEAN CROWN RATIO = 50.2

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ********FOR O.B. TOPS OF---- 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B.
1500	70	10	9.1													
				1	330	1.8	67.5	6.5	14.0	6.5						
				2	115	2.5	75.0	12.0	22.8	12.7						
				3	3	.1	77.0	14.7	1.5	.9						
					448	4.5			38.2	20.1						

ARITH. MEAN DBH = 1.3 QUADRATIC MEAN DBH =1.35 WEIBULL PARAMETERS A = .55 B = .81 C =1.84

% SURVIVAL= 100.0 MEAN CROWN RATIO = 69.5

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV HT	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES * 4-INCH CLASS AND GREATER ********FOR O.B. TOPS OF---- 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B.
1500	70	15	24.9													
				1	263	1.4	46.4	6.3	10.9	5.0						
				2	562	12.3	69.1	15.9	142.4	81.4						
				3	359	17.6	74.3	21.6	246.7	155.2						
				4	108	9.4	76.5	25.2	144.6	96.2		136.3	90.3		111.2	72.4
				5	16	2.2	77.8	27.6	35.3	24.4		34.2	23.6		30.6	20.9
				6	1	.2	78.6	29.4	3.3	2.3		3.2	2.3		3.0	2.1
					1309	43.1			583.2	364.6		173.7	116.2		148.8	95.4

ARITH. MEAN DBH = 2.3 QUADRATIC MEAN DBH =2.46 WEIBULL PARAMETERS A = .55 B =1.96 C =2.07

% SURVIVAL= 98.6 MEAN CROWN RATIO = 66.7

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ********FOR O.B. TOPS OF---******** 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B.
1500	70	20	36.4													
				1	141	.8	19.9	8.9	7.4	3.5						
				2	367	8.0	44.6	21.9	123.5	72.7						
				3	378	18.6	51.0	29.7	346.9	223.8						
				4	244	21.3	53.9	34.5	437.0	297.3		419.4	284.5		363.8	244.1
				5	109	14.9	55.5	37.8	321.6	226.8		314.7	221.6		292.0	204.6
				6	35	6.9	56.6	40.1	153.7	111.3		151.7	109.8		145.2	104.8
				7	8	2.1	57.4	41.9	48.9	36.1		48.5	35.8		47.1	34.8
				8	1	.3	57.9	43.3	8.1	6.1		8.1	6.1		7.9	5.9
					1283	72.8			1447.2	977.7		942.4	657.8		856.0	594.2

ARITH MEAN DBH = 3.0 QUADRATIC MEAN DBH =3.23 WEIBULL PARAMETERS A = .55 B =2.73 C =2.04

% SURVIVAL= 88.2 MEAN CROWN RATIO = 46.9

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES * 4-INCH CLASS AND GREATER ***FOR O.B. TOPS OF---*** 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B.
300	80	10	10.4													
				1	162	.9	61.2	6.3	6.7	3.1						
				2	104	2.3	70.7	12.1	20.8	11.6						
				3	4	.2	73.4	15.1	2.8	1.2						
					270	3.3			29.6	15.9						

ARITH. MEAN DBH = 1.4 QUADRATIC MEAN DBH =1.51 WEIBULL PARAMETERS A = .55 B = .99 C =2.09

% SURVIVAL= 100.0 MEAN CROWN RATIO = 65.1

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES * 4-INCH CLASS AND GREATER ***FOR O.B. TOPS OF---*** 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B.
300	80	15	28.4													
				1	2	.0	40.4	4.9	.1	.0						
				2	31	.7	67.0	14.7	7.4	4.2						
				3	95	4.7	72.9	21.3	64.4	40.5						
				4	115	10.0	75.4	25.6	156.1	104.0		147.3	97.6		120.6	78.6
				5	51	7.0	76.8	28.5	115.9	80.2		112.4	77.7		101.2	69.4
				6	6	1.2	77.7	30.7	20.5	14.6		20.1	14.3		18.9	13.4
					300	23.5			364.3	243.5		279.8	189.6		240.7	161.4

ARITH. MEAN DBH = 3.7 QUADRATIC MEAN DBH =3.79 WEIBULL PARAMETERS A = .55 B =3.45 C =3.73

% SURVIVAL= 100.0 MEAN CROWN RATIO = 73.8

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES * 4-INCH CLASS AND GREATER FOR O.B. TOPS OF 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B.
300	80	20	41.6													
				1	0	0.0	26.1	6.6	0.0	0.0						
				2	2	.0	49.9	20.1	.6	.4						
				3	16	.8	56.0	29.1	14.4	9.3						
				4	53	4.6	58.8	35.0	96.1	65.4		92.3	62.6		80.2	53.9
				5	98	13.4	60.4	39.1	298.2	210.7		292.0	206.1		271.8	190.9
				6	92	18.1	61.4	42.0	422.0	306.4		416.7	302.4		399.9	289.4
				7	34	9.1	62.1	44.3	219.0	162.4		217.2	161.0		211.6	156.6
				8	3	1.0	62.6	46.1	25.8	19.5		25.7	19.4		25.2	19.0
					298	47.0			1076.0	774.1		1043.9	751.5		988.7	709.8

ARITH. MEAN DBH = 5.2 QUADRATIC MEAN DBH =5.36 WEIBULL PARAMETERS A = .55 B =5.13 C =4.96

% SURVIVAL= 99.9 MEAN CROWN RATIO = 60.0

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES * 4-INCH CLASS AND GREATER FOR O.B. TOPS OF 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B.
600	80	10	10.4													
				1	230	1.3	59.4	6.2	9.4	4.4						
				2	141	3.1	70.0	12.0	28.0	15.6						
				3	8	.4	72.9	15.0	3.9	2.4						
					379	4.7			41.4	22.4						

ARITH. MEAN DBH = 1.4 QUADRATIC MEAN DBH =1.51 WEIBULL PARAMETERS A = .55 B = .98 C =1.98

% SURVIVAL= 100.0 MEAN CROWN RATIO = 63.6

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- FOR O.B. TOPS OF---- 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B.
600	80	15	28.4													
				1	31	.2	36.7	5.3	1.2	.5						
				2	146	3.2	65.1	15.3	35.8	20.4						
				3	210	10.3	71.4	21.8	145.5	91.6						
				4	147	12.8	74.1	26.0	202.8	135.2		191.6	127.2		157.4	102.9
				5	53	7.2	75.6	28.9	122.0	84.6		118.4	81.9		106.8	73.3
				6	9	1.8	76.6	31.1	31.1	22.2		30.6	21.8		28.8	20.4
				7	1	.3	77.2	32.7	4.8	3.5		4.8	3.5		4.6	3.3
					597	35.8			543.1	358.0		345.4	234.4		297.6	199.9

ARITH. MEAN DBH = 3.1 QUADRATIC MEAN DBH =3.31 WEIBULL PARAMETERS A = .55 B =2.90 C =2.63

% SURVIVAL= 100.0 MEAN CROWN RATIO = 69.2

TSO(10)	SI	AGE	AV D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES * 4-INCH CLASS AND GREATER FOR O.B. TOPS OF---- 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B.
600	80	20	41.6													
				1	5	.0	19.1	7.6	2	.1						
				2	46	1.0	44.5	21.5	15.2	8.9						
				3	120	5.9	51.1	30.4	112.6	72.7						
				4	174	15.2	54.1	36.1	325.3	222.0		312.9	212.9		273.4	184.2
				5	151	20.6	55.8	40.1	471.0	333.5		461.5	326.3		430.6	303.0
				6	77	15.1	56.9	43.0	360.6	262.2		356.3	258.9		342.2	248.0
				7	21	5.6	57.6	45.2	137.7	102.2		136.6	101.4		133.2	98.7
				8	3	1.0	58.2	46.9	26.2	19.8		26.1	19.7		25.6	19.3
					597	64.5			1448.8	1021.5		1293.4	919.2		1205.0	853.2

ARITH. MEAN DBH = 4.2 QUADRATIC MEAN DBH =4.45 WEIBULL PARAMETERS A = .55 B =4.14 C =3.21

% SURVIVAL= 99.7 MEAN CROWN RATIO = 53.3

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES FOR 0.B. 0 INCHES O.B.	I.B.	* 4-INCH CLASS AND GREATER TOPS OF---- 2 INCHES O.B.	I.B.	* 3 INCHES O.B.	I.B.
900	80	10	10.4											
				1	273	1.5	58.2	6.1	11.1	5.1				
				2	164	3.6	69.5	11.9	32.4	18.0				
				3	10	.5	72.6	14.9	4.9	3.0				
					447	5.6			48.4	26.2				

ARITH. MEAN DBH = 1.4 QUADRATIC MEAN DBH =1.51 WEIBULL PARAMETERS A = .55 B = .98 C =1.93

% SURVIVAL= 100.0 MEAN CROWN RATIO = 62.5

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES FOR 0.B. 0 INCHES O.B.	I.B.	* 4-INCH CLASS AND GREATER TOPS OF---- 2 INCHES O.B.	I.B.	* 3 INCHES O.B.	I.B.
900	80	15	28.4											
				1	112	.6	33 0	5.6	4.3	2.0				
				2	284	6.2	63.3	15.8	71.6	40.9				
				3	268	13.2	70.0	22.3	189.5	119.5				
				4	150	13.1	72.8	26.5	210.2	140.3	198.8	132.1	164.0	107.3
				5	54	7.4	74.4	29.3	125.9	87.3	122.2	84.6	110.4	75.9
				6	13	2.6	75.4	31.4	45.4	32.4	44.6	31.8	42.0	29.8
				7	2	.5	76.1	33.0	9.8	7.1	9.7	7.0	9.3	6.8
					883	43.5			656.7	429.6	375.3	255.5	325.7	219.8

ARITH. MEAN DBH = 2.8 QUADRATIC MEAN DBH =3.00 WEIBULL PARAMETERS A = .55 B =2.51 C =2.05

% SURVIVAL= 99.9 MEAN CROWN RATIO = 64.0

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ********FOR 0.B. TOPS OF---******** 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B
900	80	20	41.6													
				1	49	.3	11.7	8.6	2.5	1.2						
				2	167	3.6	38.7	22.9	58.5	34.6						
				3	230	11.3	45.7	31.7	224.6	145.6						
				4	209	18.2	48.9	37.3	402.7	275.5		387.9	264.6		340.7	230.2
				5	137	18.7	50.7	41.2	437.9	310.6		429.4	304.1		401.5	283.0
				6	67	13.2	51.9	43.9	320.3	233.2		316.5	230.3		304.4	220.9
				7	25	6.7	52.8	46.0	166.9	124.0		165.6	123.0		161.5	119.8
				8	7	2.4	53.4	47.7	62.1	46.9		61.8	46.7		60.8	45.9
				9	1	.4	53.8	49.0	11.4	8.7		11.3	8.7		11.2	8.6
					892	74.8			1686.9	1180.3		1372.5	977.4		1280.1	908.4

ARITH. MEAN DBH = 3.6 QUADRATIC MEAN DBH =3.93 WEIBULL PARAMETERS A = .55 B =3.48 C =2.22

% SURVIVAL= 99.2 MEAN CROWN RATIO = 44.8

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES * 4-INCH CLASS AND GREATER ********FOR 0.B. TOPS OF---******** 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B
1200	80	10	10.4													
				1	316	1.7	57.0	6.0	12.8	5.9						
				2	187	4.1	69.0	11.8	36.7	20.5						
				3	13	.6	72.2	14.8	6.4	3.9						
					516	6.4			55.9	30.2						

ARITH. MEAN DBH = 1.4 QUADRATIC MEAN DBH =1.51 WEIBULL PARAMETERS A = .55 B = .98 C =1.88

% SURVIVAL= 100.0 MEAN CROWN RATIO = 61.7

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- FOR 0.0 TOPS OF 0 INCHES O.B.	I.B.	*	2 INCHES O.B.	I.B.	*	3 INCHES O.B.	I.B.
1200	80	15	28.4													
				1	194	1.1	29.4	6.0	7.8	3.6						
				2	411	9.0	61.5	16.3	106.6	61.1						
				3	330	16.2	68.5	22.8	237.9	150.3						
				4	157	13.7	71.5	26.9	223.3	149.2	211.4	140.7		174.9	114.7	
				5	49	6.7	73.2	29.7	115.6	80.5	112.3	77.0		101.6	69.9	
				6	10	2.0	74.3	31.8	35.3	25.2	34.7	24.7		32.7	23.2	
				7	2	.5	75.0	33.3	9.8	7.2	9.7	7.1		9.4	6.8	
					1153	49.1			736.3	476.8	368.1	250.3		318.6	214.6	

ARITH. MEAN DBH = 2.6 QUADRATIC MEAN DBH =2.79 WEIBULL PARAMETERS A = .55 B =2.27 C =1.94

% SURVIVAL= 99.7 MEAN CROWN RATIO = 60.1

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES FOR 0.0 TOPS OF 0 INCHES O.B.	I.B.	*	4-INCH CLASS AND GREATER 2 INCHES O.B.	I.B.	*	3 INCHES O.B.	I.B.
1200	80	20	41.6													
				1	108	.6	10.0	9.8	6.0	2.9						
				2	274	6.0	32.6	24.4	101.4	60.2						
				3	306	15.0	40.1	33.1	310.3	201.8						
				4	238	20.8	43.5	38.5	472.0	323.6	455.2	311.3		401.7	272.1	
				5	141	19.2	45.4	42.2	461.3	327.6	452.5	321.0		424.0	299.4	
				6	66	13.0	46.7	44.9	321.7	234.5	318.0	231.6		306.1	222.5	
				7	25	6.7	47.6	46.8	169.7	126.2	168.4	125.2		164.4	122.0	
				8	8	2.8	48.3	48.4	72.1	54.5	71.7	54.2		70.5	53.3	
				9	2	.9	48.8	49.6	23.1	17.7	23.0	17.6		22.7	17.4	
					1168	84.9			1937.4	1349.0	1488.8	1060.9		1389.4	986.7	

ARITH. MEAN DBH = 3.3 QUADRATIC MEAN DBH =3.65 WEIBULL PARAMETERS A = .55 B =3.13 C =1.95

% SURVIVAL= 98.0 MEAN CROWN RATIO = 37.5

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ********FOR O.B. TOPS OF---- 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B.
1500	80	10	10.4													
				1	360	2.0	55.7	5.9	14.4	6.6						
				2	210	4.6	68.5	11.8	41.0	22.8						
				3	16	.8	71.9	14.8	7.8	4.8						
					586	7.3			63.3	34.2						

ARITH. MEAN DBH = 1.4 QUADRATIC MEAN DBH =1.51 WEIBULL PARAMETERS A = .55 B = .98 C =1.85

% SURVIVAL= 100.0 MEAN CROWN RATIO = 60.8

TSO(10)	SI	AGE	AV D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES * 4-INCH CLASS AND GREATER ********FOR O.B. TOPS OF---- 0 INCHES O.B.	0 INCHES I.B.	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B.	3 INCHES I.B.
1500	80	15	28.4													
				1	210	1.1	25.7	6.4	8.8	4.1						
				2	565	12.3	59.7	16.8	150.4	86.5						
				3	444	21.8	67.1	23.2	325.9	206.2						
				4	158	13.8	70.3	27.3	227.8	152.5		215.9	143.8		179.2	117.7
				5	28	3.8	72.0	30.1	66.8	46.4		64.9	45.0		58.8	40.5
				6	2	.4	73.1	32.1	7.1	5.1		7.0	5.0		6.6	4.7
					1407	53.3			786.9	500.7		287.8	193.8		244.6	162.9

ARITH. MEAN DBH = 2.5 QUADRATIC MEAN DBH =2.63 WEIBULL PARAMETERS A = .55 B =2.16 C =2.23

% SURVIVAL= 99.2 MEAN CROWN RATIO = 58.4

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ********FOR O.B. TOPS OF---******** 0 INCHES O.B.	0 INCHES I.B	*	2 INCHES O.B.	2 INCHES I.B.	*	3 INCHES O.B	3 INCHES I.B
1500	80	20	41.6													
				1	97	.5	10.0	10.9	5.9	2.8						
				2	331	7.2	26.7	25.8	128.5	76.7						
				3	421	20.7	34.6	34.3	441.3	287.8						
				4	324	28.3	38.3	39.6	658.9	452.5		636.3	435.9		563.7	382.6
				5	165	22.5	40.4	43.1	550.8	391.8		540.7	384.1		507.5	358.9
				6	57	11.2	41.7	45.7	282.6	206.2		279.4	203.8		269.2	195.9
				7	13	3.5	42.6	47.6	89.5	66.7		88.9	66.1		86.8	64.5
				8	2	.7	43.3	49.1	18.2	13.8		18.2	13.7		17.9	13.5
					1410	94.6			2175.7	1498.4		1563.5	1103.6		1445.1	1015.4

ARITH. MEAN DBH = 3.3 QUADRATIC MEAN DBH =3.51 WEIBULL PARAMETERS A = .55 B =3.06 C =2.26

% SURVIVAL= 95.3 MEAN CROWN RATIO = 33.0

Farrar, Robert M., Jr. 1985. Predicting stand and stock tables from a spacing study in naturally regenerated longleaf pine. U.S. Dep. Agric. For. Serv. Res. Pap. SO-219, 28 p. South. For. Exp. Stn., New Orleans, LA.

Paper outlines a prediction system developed to calculate stand and stock tables for stands of natural longleaf pine 10 to 20 years old. The system also provides entry to other stand volume prediction and projection systems that usually start at age 20.

Additional keywords: *Pinus palustrus;* volume prediction; volume yields; crown ratio, survival prediction.

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Volume and Growth Predictions for Thinned Even-Aged Natural Longleaf Pine Stands in the East Gulf Area

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Volume and Growth Predictions for Thinned Even-Aged Natural Longleaf Pine Stands in the East Gulf Area

Robert M. Farrar, Jr.

INTRODUCTION

Encouraged by the high quality and marketability of longleaf pine (*Pinus palustris* Mill.), many landowners are taking advantage of recent improvements in longleaf regeneration techniques (Mann 1969, 1970; Croker and Boyer 1975; Farrar and White 1983; Dennington and Farrar 1983) and are growing longleaf pine today.

Successful longleaf timber management demands predictable growth and yield resulting from various management alternatives. Guidance exists in yield tables for unthinned naturally regenerated stands (Schumacher and Coile 1960, Forest Service 1976) and for unthinned plantations (Lohrey and Bailey 1977). Lohrey (1976) also provides information on thinned plantations. Research Paper SO-156 (Farrar 1979) described growth and yield predictions for a comprehensive array of stand ages, site qualities, and residual densities maintained by periodic thinning in natural stands. Research was based on the first 5-year growth in a regional natural longleaf pine growth study.

This paper updates SO-156 and describes a more versatile system for stand volume and volume growth prediction. Data from the first and second 5-year growth periods allow estimates of total and merchantable stand volume in cubic feet, cords, dry weight, and board feet (fbm).

METHODS[1]

Field Procedures

This study comprises 209 permanent 1/5- and 1/10-acre plots, established with the cooperation of private and public landowners (see Acknowledgements), in even-aged natural stands of longleaf pine in northwest Florida, southwest Georgia, south and central Alabama, and south Mississippi.

Plots were chosen to reflect variety in stand age, site index, and residual basal area classes. Plots chosen were at least 80 percent longleaf (by total basal area) before cutting (100 percent after cut); uniform in age, site index, and density; and free of damage from insects, disease, wildfire, turpentining, etc. All hardwoods with d.b.h. > 0.5 inch were killed initially.

Initial field measurements included numbering and tallying all living longleaf stems with d.b.h. > 0.5 inch and recording crown class (SAF 1958) for each tree. To determine tree heights, a sample of trees was systematically selected from each 1-inch d.b.h. class and measured for total height and height to the live crown base (see Farrar 1978). A subsample of dominant and co-dominant trees was similarly chosen to determine stand age and site index.

Most plots have been prescription burned every 3 to 5 years to control woody vegetation regrowth and reduce wildfire hazard.

All longleaf with d.b.h. ≤ 0.5 inch were destroyed. Plots were thinned initially using an improvement cut/low thinning and, after remeasurement, rethinned using low thinning. These thinnings left a specified residual basal area per plot.

At each remeasurement, at 5-year intervals, field procedures are identical to the initial procedures; in addition, the amount and causes of mortality are identified. Plots are rethinned to initial density levels if basal areas have grown more than 1/4 of the way toward the midpoint of the next higher basal area class.

Data Summary

Plot basal areas, volumes per acre, and site index were calculated using procedures identical to Farrar (1978, 1979).

The stand basal area and volumes were partitioned into three components:

[1]Farrar (1978) gives details for all field procedures.

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(1) total = including all trees with d.b.h > 0.5 inch,
(2) merchantable = including only those trees with d.b.h. > 3.5 inches,
and (3) sawtimber = including only those trees with d.b.h. > 9.5 inches.

For reference, the site index function (Farrar 1981) is:

$$(1) \qquad S = (Hd)(10)^{(f50-fA)}$$

where S = stand site index in feet, index age 50 years
Hd = average height of dominant and co-dominant sample trees in feet
$f50 = b1/50 + b2/50^2 + b3/50^3 + b4/50^4$
A = average age of dominant and co-dominant sample trees in years
$fA = b1/A + b2/A^2 + b3/A^3 + b4/A^4$
b1 = −29.468
b2 = 938.97
b3 = −16102
b4 = 88775.

Data Analysis

In the analysis, 188 plots were used. Of these plots, 64 have been remeasured once and 124 twice, resulting in 312 observations on growth (table 1). Twenty-one plots were omitted due to destruction before remeasurement, excessive mortality in the dominant and co-dominant crown classes, or suspected adverse effects of disease and site alteration caused by a raised water table. If the periodic mortality exceeded 5 percent of the initial basal area in dominant and co-dominant trees, the plot was excluded; otherwise, any mortality in the intermediate and suppressed crown classes was tolerated.

Therefore, the observations used in this analysis represent the net volume growth and yield one might expect in the absence of catastrophic mortality or other adverse influences.

Table 1 shows the distribution of these 312 observations by initial age (A1), site index (S), and residual total basal area (BT1). Initially, individual plots varied in age from 15 to 90 years, in site index from 46 to 90 feet, and in total basal area from 8 to 169 square feet per acre.

The analysis utilizes the concept of a simultaneous stand volume and volume growth prediction system, advanced by Sullivan and Clutter (1972), wherein the developed system allows the prediction of growth increments which sum to give stand yield. Total, merchantable, and sawtimber stand volume functions, which allow estimates of both present and future volumes, were fitted based on observations of initial and final stand volumes and the Schumacher yield model (Schumacher 1939). The number of observations in-

Table 1.--*Number of observations by site, age, and total residual basal area classes*

S. I. Class	Age Class	Residual total basal area class (sq. ft./acre)						
		≤16	16–45	46–75	76–105	106–135	136–165	>165
ft	*yrs.*	*number*						
46–55	11–30	1	4		2	1		
	31–50		1	4	7	3	1	
	51–70		3	1	2	1	2	
	71–90		2	2	3	2		
56–65	11–30	2	11	6	3			
	31–50		4	3	3	5	1	
	51–70		4	7	2	2	5	
	71–90		2	1	3	1		
66–75	11–30	1	15	6	4	3		
	31–50		4	4	4	5	3	
	51–70		4	6	6	9		2
	71–90		3	6	6	4	4	
76–85	11–30		8	8	5	7	4	
	31–50		3	4	6	5	3	
	51–70		5	5	6	4	3	
	71–90				2			
86–95	11–30							
	31–50		4	2	2		1	
	51–70		2	3	1	1		
	71–90							

volved in total and merchantable cubic-foot estimators was 624, while 437 observations were involved in sawtimber volume estimators (those observations where sawtimber basal area was > 0).

A modified form of the Chapman-Richards growth function (Moser and Hall 1968, Pienaar and Turnbull 1973, Pienaar 1979) was fitted in integral form using 312 observations on basal area growth to obtain a projected total basal area (BT2) estimator. A second modification of the Chapman-Richards function was fitted in integral form using 203 observations to obtain a projected sawtimber basal area (BS2) estimator (Murphy 1983a). The BS2 function uses only those observations where initial sawtimber basal area (BS1) was > 0. All functions were fitted via nonlinear least squares (SAS Institute 1979, 1980).

RESULTS

The equations developed to project the total and sawtimber basal areas and to estimate the current and future stand volumes for thinned natural longleaf are as follows:

Total Basal Area

$$(2)\qquad BT2 = \{N/K - [N/K - (BT1)^{(1-M)}]$$

$$(A2/A1)^{(-K(1-M))}\}^{(1/(1-M))}$$

where BT2 = projected total basal area at the end of the growth period in square feet per acre; d.b.h. > 0.5 inch
BT1 = total basal area at the start of the growth period
A2 = stand age at the end of the growth period in years
A1 = stand age at the start of the growth period
N = −1.0007
K = −5.6643
M = 1.3213.

Equation (2) is based on 312 observations on total basal area growth. Note that in equation (2) when A1 = A2 then BT1 = BT2 and BT2 predicted by projecting from A1 to A2 to A3 is identical to projecting from A1 directly to A3.

Sawtimber Basal Area

$$(3)\qquad BS2 = (BT2)\{1 - [1 - (R1)^{J}](A2/A1)^{(JP)}\}^{(1/J)}$$

where BS2 = projected sawtimber basal area at the end of the growth period in square feet per acre; d.b.h. > 9.5 inches
BS1 = sawtimber basal area at the start of the growth period
R1 = BS1/BT1
J = −0.68920
P = 6.8131.

Equation (3) is based on 203 observations on sawtimber basal area growth for plots where BS1 > 0 and has the same features as equation (2). Sawtimber basal area, in all cases, is a subset of total basal area (it is contained within total basal area). The observed average BT1, BS1, and resulting R1 by A1, S, and BT1 classes are shown in table 2. Note further that equation (3) is not usable if BS1 = 0. A BS1 > 0 must be observed, or be hypothesized, to predict a BS2. Therefore, equation (3) permits simulation of net sawtimber basal area growth, including ingrowth, if BS1 > 0 but sawtimber ingrowth from a state of zero BS1 cannot be simulated.

Considerable effort was expended to include site index in some form in both equations (2) and (3) but to no avail. No significant effect of site index on projected basal area could be detected.

Total Cubic-foot Volumes

$$(4)\qquad VIT = EXP[2.7946 + 0.015344(S) - 21.904/A$$

$$+0.976810\ln(BT))]$$

where VIT = predicted total stand volume in cubic feet, i.b., per acre; d.b.h. >0.5 inch, 0.2-foot stump; current or future
EXP = base e raised to the ( ) power
S = stand site index in feet; index age 50 years, equation (1) assumed
A = stand age in years; either A1 or A2
ln = natural logarithm (base e)
BT = stand total basal area per acre in square feet; d.b.h. >0.5 inch; either BT1 or BT2 (corresponding to either A1 or A2 above).

Equation (4) is based on 624 observations on total cubic-foot, i.b., stand volume (312 at A1 plus 312 at A2).

$$(5)\qquad VOT = EXP[2.9966 + 0.013375(S) - 17.467/A$$

$$+0.99700(\ln(BT))]$$

where VOT = predicted total stand volume in cubic feet, o.b., per acre; d.b.h. >0.5 inch, 0.2-foot stump; current or future.

Equation (5) is based on 624 observations on total cubic-foot, o.b., stand volume.

Table 2.—*Observed average sawtimber and total basal areas and R1 ratios*[1]

S. I. class	Age class	Residual total basal area class (sq.ft./acre) <16 BS1	<16 BT1	<16 R1	16–45 BS1	16–45 BT1	16–45 R1	46–75 BS1	46–75 BT1	46–75 R1
ft.	*yrs.*	*– sq.ft./acre –*			*– sq.ft./acre –*			*– sq.ft./acre –*		
46–55	11–30	0	8	0	0	26	0	....	....	....
	31–50	....	.....	....	0	30	0	0	61	0
	51–70	....	.....	....	10	32	.30	50	65	.77
	71–90	....	.....	....	32	32	1.0	67	67	1.0
56–65	11–30	0	13	0	0	31	0	0	57	0
	31–50	....	.....	....	2	33	.07	12	62	.20
	51–70	....	.....	....	25	31	.82	42	61	.69
	71–90	....	.....	....	33	33	1.0	60	60	1.0
66–75	11–30	0	15	0	0	31	0	0	60	.01
	31–50	....	.....	....	24	33	.73	14	63	.22
	51–70	....	.....	....	33	33	1.0	56	62	.90
	71–90	....	.....	....	34	34	1.0	63	63	1.0
76–85	11–30	....	.....	....	5	31	.15	0	58	.01
	31–50	....	.....	....	22	34	.66	57	62	.92
	51–70	....	.....	....	33	33	1.0	61	61	1.0
	71–90	....	.....	....	....	....	....	....	....	....
86–95	11–30	....	.....	....	....	....	....	....	....	....
	31–50	....	.....	....	32	34	.94	30	64	.47
	51–70	....	.....	....	31	31	1.0	61	61	1.0
	71–90	....	.....	....	....	....	....	....	....	....

S. I. class	Age class	Residual total basal area class (sq.ft./acre) 76–105 BS1	76–105 BT1	76–105 R1	106–135 BS1	106–135 BT1	106–135 R1	>135 BS1	>135 BT1	>135 R1
ft.	*yrs.*	*– sq.ft./acre –*			*– sq.ft./acre –*			*– sq.ft./acre –*		
46–55	11–30	0	90	0	0	121	0	....	....	....
	31–50	6	92	.06	7	116	.06	6	137	.04
	51–70	29	91	.32	16	112	.14	57	154	.37
	71–90	82	91	.91	68	116	.58	....	....	....
56–65	11–30	0	83	0	....	....	....	....	....	....
	31–50	1	92	.01	6	117	.06	27	145	.18
	51–70	39	91	.43	47	122	.38	44	147	.30
	71–90	85	91	.94	109	114	.96	....	....	....
66–75	11–30	0	94	0	0	110	0	....	....	....
	31–50	28	90	.31	13	123	.10	25	151	.16
	51–70	76	90	.84	94	113	.83	101	168	.60
	71–90	92	92	1.0	103	117	.88	....	....	....
76–85	11–30	3	92	.04	6	120	.05	6	147	.04
	31–50	32	92	.35	25	121	.21	23	149	.15
	51–70	86	90	.96	82	121	.67	145	149	.97
	71–90	84	90	.93	....	....	....	....	....	....
86–95	11–30	....	.....	....	....	....	....	....	....	....
	31–50	69	91	.76	....	....	....	48	149	.32
	51–70	92	92	1.0	112	118	.95	....	....	....
	71–90	....	.....	....	....	....	....	....	....	....

[1]R1 = BS1/BT1

Merchantable Cubic-foot Volumes

Prediction equations for mechantable cubic-foot stand volumes could not be developed using the same functional form as for total and sawtimber cubic-foot volumes (presented later) because of intersection of the fitted merchantable cubic-foot equations with other cubic-foot equations. Therefore, stand merchantable cubic-foot volumes are estimated via a fitted common ratio estimator designed to alleviate the intersection problem:

(6) $$VIM = VIT/RE$$

where VIM = predicted merchantable stand volume in cubic feet, i.b., per acre; d.b.h. > 3.5 inches, 3-inch top d.o.b., 0.2-foot stump; current or future and

$$RE = \{1 + EXP[2.5850 + 321.77/S + 9411.2/((S)(BT)) - 2.8274(\ln(A)) - 3417.1(\ln(A))/((S)(BT))]\}.$$

Equation (6) is based on 1,248 observations on merchantable cubic-foot stand volume (i.b. and o.b.).

(7) $$VOM = VOT/RE$$

where VOM = predicted merchantable stand volume in cubic feet, o.b., per acre; d.b.h. > 3.5 inches, 3-inch top d.o.b., 0.2-foot stump; current or future.

Sawtimber Volumes

The following equations are based on 437 observations where either the initial or final sawtimber basal area was >0.

(8) $$VIS = EXP[2.7379 + 0.015684(S) - 29.352/A + 0.99614(\ln(BS))]$$

where VIS = predicted sawtimber stand volume in cubic feet, i.b., per acre; d.b.h. > 9.5 inches, 7-inch top d.o.b., 0.2-foot stump; current or future.

BS = sawtimber basal area per acre in square feet; d.b.h. > 9.5 inches; either BS1 or BS2 corresponding to A1 or A2, respectively.

(9) $$VOS = EXP[2.9544 + 0.014474(S) - 25.431/A + 1.0019(\ln(BS))]$$

where VOS = predicted sawtimber stand volume in cubic feet, o.b., per acre; d.b.h. > 9.5 inches, 7-inch top d.o.b., 0.2-foot stump; current or future.

(10) $$BF = EXP[4.2210 + 0.019257(S) - 30.001/A + 1.0207(\ln(BS))]$$

where BF = predicted stand board-foot volume per acre, International 1/4-inch rule; d.b.h. > 9.5 inches, 5-inch top d.i.b., 1-foot stump; current or future.

Evaluation of Equations

"Goodness of fit" statistics for equations (2) through (10) are given in table 3. In general, the values in table 3 indicate that the system predictors track the data well. The mean difference ($\bar{d}$) and percent mean difference ($\overline{\%d}$) figures for the stand volume values herein are comparable to or less than those in SO-156 and similar to or much lower than those for recently published systems for loblolly and shortleaf pines (Murphy 1982, 1983b; Murphy and Beltz 1981). There is a generally consistent small positive bias, indicated by the $\bar{d}$ and $\overline{\%d}$ figures, but it seems tolerable. The precision, indicated by the RMSd and %RMSd figures, although variable, also appears acceptable. The fit index (FI) is a measure of the variation accounted for by the predictive equation or system. It is analogous to the coefficient of determination in regression (r^2 or R^2) and takes on values ≤ 1. FI is used to evaluate variation accounted for by conditioned or transformed linear regression or non-linear regression, or systems thereof, where the coefficient of determination is not appropriate. The FI figures in table 3 indicate adequate accounting of variation in the dependent variables by the predictors without excessive lack of precision or excessive bias. Low positive or negative values for FI would indicate poor fit due to poor precision and/or excessive bias.

Pulpwood Volumes

Pulpwood stand volumes (the cubic-foot volume in trees between 3.5 and 9.5 inches d.b.h. and the volume in the tops of sawtimber trees between 7 and 3 inches d.o.b.) can be estimated as:

(11) $$VIP = VIM - VIS, \text{ or } VOP = VOM - VOS,$$

where VIP and VOP are pulpwood volumes i.b. and o.b., respectively.

Quick and crude estimates of cords in pulpwood can be obtained as: VIP/80 for inside-bark or VOP/90 for outside-bark.

Table 3.—*Goodness of fit statistics for values predicted by equations (2) through (10) and (13)*

Value	Eq.#	n	$\bar{o}$	$\bar{d}$	RMSd	$\overline{\%d}$	RMS%d	FI
BAT2	(2)	312	91	.6	4.6	1.5	6.1	.985
BAS2	(3)	203	62	.1	5.6	2.5	22.7	.974
VIT1	(4)	312	1933	24.0	90.0	2.5	6.6	.995
VIT2*	(4)	312	2415	4.3	168.4	.7	8.1	.982
VOT1	(5)	312	2503	27.3	91.9	1.9	5.0	.996
VOT2*	(5)	312	3107	7.4	195.7	.8	7.5	.984
VIM1	(6)	312	1832	38.4	141.0	8.3	30.2	.988
VIM2*	(6)	312	2319	15.9	194.9	1.0	11.1	.977
VOM1	(7)	312	2356	53.6	175.1	8.4	29.7	.988
VOM2*	(7)	312	2970	29.0	234.6	1.4	10.4	.978
VIS1	(8)	203	1433	10.2	46.6	.5	5.7	.998
VIS2*	(8)	203	1834	−4.3	143.5	1.2	19.9	.986
VOS1	(9)	203	1782	12.1	49.8	.4	4.8	.999
VOS2*	(9)	203	2274	−4.0	178.9	1.4	20.2	.985
BF1	(10)	203	8977	89.4	411.9	2.6	9.8	.997
BF2*	(10)	203	11544	−4.2	949.6	2.3	21.5	.985
D	(13)	624	8.47	.0001	.9441	1.8	14.2	.936

*All predictors for volume at the end of the period use projected basal area as the argument for basal area.

n = number of observations
$\bar{d}$ = average difference between predicted (p) and observed (o)
$= [\text{sum}(p-o)]/n$
$\text{RMS\%D} = \sqrt{\{[\text{sum}((p-o)/o)^2]/n\}}(100)$

$\bar{o}$ = average observed value
$\text{RMSd} = \sqrt{[\text{sum}(p-o)^2]/n}$
$\overline{\%d} = [\text{sum}((p-o)/o)/n](100)$
FI = fit index
$= 1 - [\text{sum}(o-p)^2/\text{sum}(o-\bar{o})^2]$

Cordwood Conversion

For cordwood conversions, the system employed in SO-156 is used again with updated equations for VIT and D:

$$(12)\quad C5 = (VIT)[0.0126 - 0.0056/D - 0.01989/(D^2)]$$

where C5 = estimated rough cords per acre; d.b.h. > 5 inches, 4-inch top d.o.b., 0.7-foot stump
D = predicted quadratic mean stand d.b.h.; all trees with d.b.h. > 0.5 inch (d.b.h. of the tree of mean basal area)

and

$$(13)\quad D = -1.0029 + 0.0013562(A^2) + 0.0047379(A)(S) - 0.00091464(A)(BT) - 0.000039501(A^2)(S) + 0.0000062696(A^2)(BT).$$

Equation (13) is based on 624 observations and can estimate either initial or final D depending on the arguments for A and BT. The fit statistics for this equation are shown in table 3.

To get an estimate of the cord volume in pulpwood, the following equations can be used:

Let:

VOP = (VOM − VOS) = cubic-foot volume in pulpwood
CS = cords in sawtimber and
CP = (C5 − CS) = cords in pulpwood.

Assume that:

$$(VOM - VOS)/VOM = (C5 - CS)/C5.$$

Then,

$$(14)\quad CP = [(C5)(VOP)]/VOM.$$

Schumacher and Coile (1960) used stand total cubic-foot volume, i.b., and quadratic mean stand d.b.h. as arguments to derive equation (12). The arguments here differ slightly in definition, but the difference is not great enough to prohibit useful estimates. Since cord volume was not actually observed, no fit statistics for equations (12) and (14) are possible.

Dry Weight

To estimate dry weight of wood per acre, use estimates of VIM or VIS and wood specific gravity values from Appendix tables 29–36 in Wahlgren and Schumann (1975) may be used as follows:

(15) $WIM = (VIM)(62.4)(SGA)$ and

(16) $WIS = (VIS)(62.4)(SGS)$

where WIM = approximate wood dry weight in pounds per acre; for the stand with d.b.h. > 3.5 inches, 3-inch top d.o.b., 0.2-foot stump

SGA = average tree specific gravity, all d.b.h. classes (Wahlgren and Schumann 1975)

WIS = approximate wood dry weight in pounds per acre; for the stand with d.b.h. > 9.5 inches, 7-inch top d.o.b., 0.2-foot stump

SGS = average tree specific gravity, sawtimber classes (d.b.h. > 9.0 inches) (Wahlgren and Schumann 1975).

The merchantability specifications used here differ somewhat from Wahlgren's and Schumann's, but the weight estimates should be satisfactory for most purposes.

APPLICATION

Preliminaries

Equations (2) through (16) provide the means for simulating a wide variety of thinnning schedules and rotation lengths both for existing and hypothetical stand conditions. Initial conditions should be:

A1 = 20 to 80 years
S = 46 to 95 feet
BT1 = 16 to 165 square feet
BS1 = similar to the values shown in table 2.

The minimum initial age (A1) may be 15 years but 20 is preferable because site index estimates are more precise at older ages. Also, ingrowth above merchantability thresholds may have a sudden and highly variable effect at young ages. It is possible to start predictions as early as age 10 for site index 70 and 80 stands by using (a) information on stand density as surviving trees per acre at this early age and (b) the predictors in Farrar (1985). But, again, this is risky for the above reasons.

Because the system of equations herein is based on stands essentially thinned from below for one or two 5-year growth periods, it is prudent to restrict projections to short periods—preferably 5 to 10 years but probably no more than 30 years at the most. Single long-term projections are not as reliable as short-term projections and also exclude long-term mortality effects. Forecasting production to age 80 for a thinning regime starting at age 30 and employing 5- or 10-year cutting intervals is preferable to forecasting production of an unthinned stand from age 30 to 80.

Although the fit statistics (table 3) indicate that sawtimber volume predictions are about as reliable as those for total and merchantable cubic feet, a qualification is necessary. This system predicts a unique set of volumes for any given combination of A, S, and BT or BS, regardless of the way a stand may have reached that condition. For stand total and merchantable cubic-foot volume, in general, this is reasonable because such volumes are largely a function of age, site index, and total basal area of the stand without regard to the size distribution of the stems. But, the nature of the diameter distribution of the stand above the sawtimber threshold is very important in determining stand sawtimber cubic-foot and board-foot volumes, especially for a highly diameter-dependent log rule such as Doyle.

Many of the stands in this study have grown under their prescribed densities for only 5 to 10 years, not for all or most of their lives, and their diameter distributions and predicted sawtimber responses probably do not yet completely reflect the density treatments imposed, particularly in the older age classes. International 1/4-inch volumes, similar to cubic-foot volumes, should be less sensitive to these circumstances than, for example, Doyle rule volumes. Because the International 1/4 rule most accurately reflects the board-foot content of a tree recoverable by an efficient band mill, it does not penalize small or large trees as do the Doyle and Scribner rules, respectively.

However, a true picture of treatment-induced diameter distributions and sawtimber-sized material will emerge when the 20-year age-class plots initially established have been managed under the imposed density levels by thinning periodically over a rotation of at least 60 years. Some users would prefer a rotation of 80 years or longer.

Since sawtimber predictions here are most likely to largely reflect the unknown stand histories occurring before the stands were included in the study, they should be used with caution. Additional inventories and analyses should provide better sawtimber volume estimates because, as time passes, more of the stands will have been managed under their prescribed density levels.

The Appendix contains tables showing predicted current and future basal areas and volumes for an extensive array of initial and final ages, site indices, and basal areas at the initial age. For convenience, the complete array of predicted values is often presented in these tables, but certain combinations,

though possible, are highly improbable because they represent stand conditions not likely to be found—i.e., a 20-year old stand on site index 50 containing 150 square feet of total basal area with R1 = BS1/BT1 = 100 percent. Readers are cautioned, when using these tables, to specify reasonable stand conditions.

Appendix tables 1 through 28 give VIT and VOT volume estimates plus BT2 estimates; tables 29 through 56 give VIM and VOM estimates; table 57 gives BS2 estimates; and tables 58 through 60 give VIS, VOS, and BF estimates. Through these tables, the equation system has been made usable by those without significant computing facilities. However, the equation system can be used to make predictions for many combinations of initial and final stand conditions not shown in the Appendix tables.

The system is easily incorporated into computer simulation programs or adapted to electronic spreadsheet software widely available for micro-computers. In fact, the equation system has been programmed on two magnetic strips for the TI-59/PC-100C hand-held computer/printer[2]. The program code listing is available free of charge on request from the Southern Forest Experiment Station Silvicultural Laboratory at Monticello, Arkansas, along with program documentation and test problem. Also available upon request are the cell contents listing (operations, functions, etc.) and example output from the SuperCalc[2] electronic spreadsheet program for an 8-bit CP/M microcomputer. The cell contents listing will allow easy adaptation of this prediction system to any similar program as long as it has or exceeds the capability of SuperCalc.

Figure 1 illustrates the function of the system of equations to predict current volumes for a stand and to project the basal areas for a growth period and to obtain the future stand volumes.

[2]Use of trade names does not imply endorsement by the USDA Forest Service. Such names are used only for illustrative purposes and other similar items may serve just as well.

Examples

Table 4 gives four examples illustrating use of the prediction system and associated Appendix tables. Each example assumes that initial stand and operating conditions are:

A1 = 30 years
S = 70 feet at 50 years
BT1 (before cut) = 100 square feet
BS1 (before cut) = 5 square feet
rotation = 60 years
cutting interval = 5 years
thinning = from below

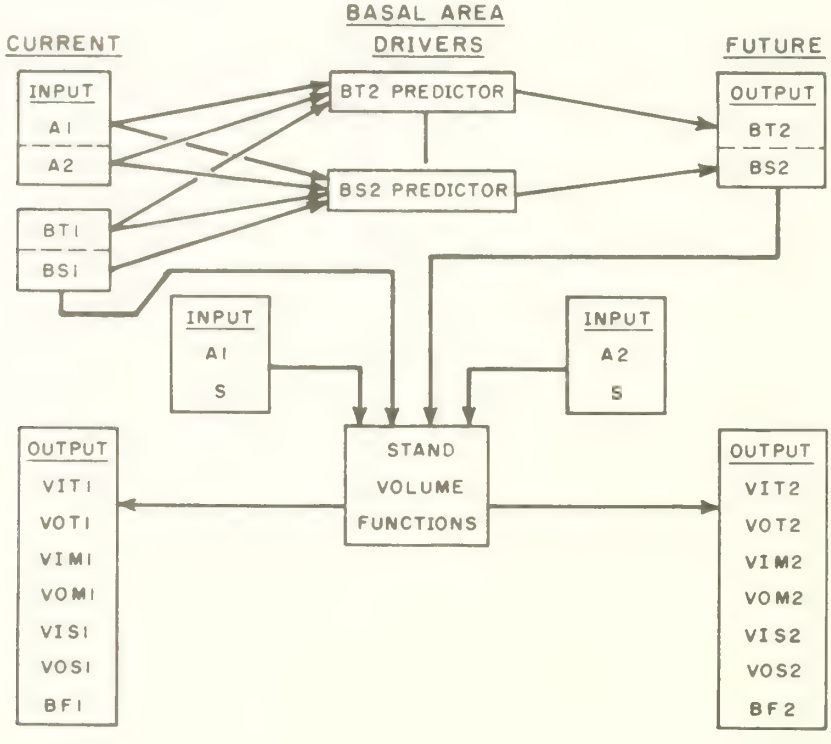

Figure 1.—*Schematic of System Operation (abbreviated).*

Age	Before-cut stand							After-cut stand							Cut stand						
	BT	VIT	VOT	BS	VIS	VOS	BF	BT	VIT	VOT	BS	VIS	VOS	BF	BT	VIT	VOT	BS	VIS	VOS	BF
Example 1 (similar to example 1 in SO-156)																					
30	100	2073	2813	5	87	114	499	70	1463	1971	5	87	114	499	30	610	842	0	0	0	0
35	89	2061	2732	14	277	359	1645	70	1624	2142	14	277	359	1645	19	437	590	0	0	0	0
40	87	2165	2823	30	659	845	3986	70	1756	2280	21	462	591	2770	17	409	543	9	197	254	1216
45	85	2249	2895	38	904	1149	5515	70	1867	2393	28	667	847	4039	15	382	502	10	237	302	1476
50	83	2318	2954	45	1142	1441	7005	60	1686	2134	36	914	1152	5578	23	632	820	9	228	289	1427
55	71	2080	2620	50	1338	1677	8238	30	891	1104	30	804	1005	4891	41	1189	1516	20	534	672	3347
60	38	1146	1416	38	1064	1324	6515	0	0	0	0	0	0	0	38	1146	1416	38	1064	1324	6515
														Yield =	183	4805	6229	86	2260	2841	13981
														M.a.i. =	3.1	80	104	1.4	38	47	233
Example 2 (increasing residual total basal area)																					
30	100	2073	2813	5	87	114	499	70	1463	1971	5	87	114	499	30	610	842	0	0	0	0
35	89	2061	2732	14	277	359	1645	75	1738	2295	14	277	359	1645	14	323	437	0	0	0	0
40	92	2290	2989	32	703	901	4258	80	2001	2605	24	527	676	3174	12	289	384	8	176	225	1084
45	95	2515	3244	42	999	1270	6108	85	2257	2905	34	809	1028	4923	10	258	339	8	190	242	1185
50	98	2733	3494	53	1345	1697	8279	60	1686	2134	42	1066	1344	6529	38	1047	1360	11	279	353	1750
55	71	2080	2620	56	1498	1879	9249	30	891	1104	30	804	1005	4891	41	1189	1516	26	694	874	4358
60	38	1146	1416	38	1064	1324	6515	0	0	0	0	0	0	0	38	1146	1416	38	1064	1324	6515
														Yield =	183	4862	6294	91	2403	3018	14892
														M.a.i =	3.1	81	105	1.5	40	50	248
Example 3 (decreasing residual total basal area)																					
30	100	2073	2813	5	87	114	499	70	1463	1971	5	87	114	499	30	610	842	0	0	0	0
35	89	2061	2732	14	277	359	1645	65	1511	1990	14	277	359	1645	24	550	742	0	0	0	0
40	82	2036	2651	31	681	873	4122	60	1511	1955	24	527	676	3174	22	525	696	7	154	197	948
45	74	1976	2536	41	976	1240	5960	55	1475	1882	33	785	998	4776	19	501	654	8	191	242	1184
50	68	1885	2391	48	1218	1537	7483	60	1686	2134	40	1016	1280	6212	8	199	257	8	202	257	1271
55	71	2080	2620	54	1444	1811	8912	30	891	1104	30	804	1005	4891	41	1189	1516	24	640	806	4021
60	38	1146	1416	38	1064	1324	6515	0	0	0	0	0	0	0	38	1146	1416	38	1064	1324	6515
														Yield =	182	4720	6123	85	2251	2826	13939
														M.a.i =	3.0	79	102	1.4	38	47	232
Example 4 (similar to example 3 in SO-156)																					
30	100	2073	2813	5	87	114	499	100	2073	2813	5	87	114	499	0	0	0	0	0	0	0
50	157	4326	5583	78	1976	2500	12282	60	1686	2134	60	1521	1922	9396	97	2640	3449	18	455	578	2886
55	71	2080	2620	71	1898	2383	11783	30	891	1104	30	804	1005	4891	41	1189	1516	41	1094	1378	6892
60	38	1146	1416	38	1064	1324	6515	0	0	0	0	0	0	0	38	1146	1416	38	1064	1324	6515
														Yield =	176	4975	6381	97	2613	3280	16293
														M.a.i. =	2.9	83	106	1.6	44	55	272

minimum sawtimber cut = about 1Mbf
regeneration = shelterwood preparatory cut at age 50, seed cut at age 55, and removal cut at age 60.

Example 1 assumes a constant residual BT of 70 square feet is left after each cut. Example 2 assumes that an increasing BT is left after each cut. Example 3 assumes a decreasing BT and Example 4 assumes no intermediate cuts. All basal area and volume values for these examples can be found or interpolated in the Appendix tables.

For Example 1 the values are obtained as follows: Enter Appendix table 9 at initial total basal area (BT1) = 100, initial age (A1) = 30 years, and site index (S) = 70; read 2,073 total cubic feet, i.b. (VIT). Similarly, enter Appendix table 23 for the same conditions and read 2,813 total cubic feet, o.b. (VOT). Enter Appendix table 58 at age (A) = 30, sawtimber basal area (BS) = 5, and S = 70 and read 87 sawtimber cubic feet, i.b. (VIS). Similarly, enter table 59 and table 60 for these same sawtimber stand conditions and read 114 sawtimber cubic feet, o.b. (VOS) and 499 fbm Int. 1/4 rule (BF). These are the before-cut standing volumes at age 30.

We want to thin from below at age 30 and leave BT = 70. We leave BS = 5 because we do not want to sacrifice any of our sawtimber stand now (assuming it is all good growing stock). To obtain the after-cut stand volumes, we proceed as follows: Enter Appendix table 6 at BT1 = 70, A1 = 30, A2 = 30, S = 70, and read VIT = 1,463. With the same stand conditions, enter Appendix table 20 and read VOT = 1,971. Since we are not cutting any sawtimber basal area, the sawtimber volumes remain the same in the after-cut stand as in the before-cut stand. We obtain the cut-stand values at age 30 by subtracting the after-cut values from the before-cut values, item by item.

Now, to project the after-cut stand forward 5 years in time, enter Appendix table 6 at BT1 = 70, A1 = 30, A2 = 35, S = 70, and read VIT2 = 2,061 and BT2 = 89. Similarly, from Appendix table 20 we find VOT2 = 2,732 (and, again, BT2 = 89). Enter Appendix table 57 at A1 = 30, A2 = 35, BT1 = 70, and R1 = 5/70 = 0.07 and interpolate BS2 = 14. Then, in tables 58, 59, and 60 for A = 35, S = 70, and BS = 14, interpolate VIS2 = 277, VOS2 = 359, and BF2 = 1,645. These are, for practical purposes, the projected stand values, before cut, at age 35.

Again, at stand age 35, we thin to leave BT = 70 and, since our sawtimber volume is unlikely to support a commercial cut, we leave the BS = 14. To get after-cut stand values at age 35, enter Appendix table 6 at BT1 = 70, A1 = 35, A2 = 35, S = 70, and read VIT = 1,624. Similarly, in table 20 read VOT = 2,142. Again, since we did not cut any sawtimber, the BS, VIS, VOS, and BF values remain the same as before cut.

We now project the stand from age 35 to 40 by again entering Appendix table 6 at BT1 = 70, A1 = 35, A2 = 40, and S = 70. Read VIT2 = 2,165 and BT2 = 87. Similarly, in Appendix table 20, read VOT2 = 2,823. In Appendix table 57 for A1 = 35, A2 = 40, BT1 = 70 and R1 = 14/70 = 0.2, read BS2 = 30. Now, in tables 58, 59, and 60 for A = 40, S = 70, and BS = 30, read VIS = 659, VOS = 845, and BF = 3,986, respectively. These are the projected stand values, before cut, at age 40.

Again, at age 40, we cut to leave BT = 70 and now we can make a sawtimber thinning to provide a cut > 1Mbf. We can do this by reducing the BS from 30 to 21 or cutting about 30 percent. To obtain the after-cut values, enter Appendix table 6 at BT1 = 70, A1 = 40, A2 = 40, S = 70, and read VIT = 1,756. Similarly, from table 20, VOT = 2,280. Entering tables 58, 59, and 60 at A = 40, S = 70, and BS = 21, we interpolate VIS = 462, VOS = 591, and BF = 2,770, respectively. We obtain our cut-stand values at age 40 by subtracting after-cut values from before-cut values.

This procedure is repeated until at age 60 we have projected values of BT = 38, VIT = 1,146, VOT = 1,416, BS = 38, VIS = 1,064, VOS = 1,324, and BF = 6,515. At this time we harvest the shelterwood stand. Note that at ages 45 and 50 we cut about 1/4 of the sawtimber basal area and assumed at age 50 that all of the residual basal area would be in sawtimber. Note also that it is conceptually impossible to have a sawtimber basal area cut greater than a total basal area cut since the BS is imbedded in the BT. Estimate the net yields by summing the cut values over the rotation. We can then estimate the mean annual increment (m.a.i.) for the rotation by dividing the yields by 60.

The values for the other three examples in table 4 were obtained in similar fashion.

Under the specified conditions, these examples suggest that:

(a) thinning reduces net yields,
(b) thinning to periodically increase the residual BT resulted in the greatest yield among the thinning examples, and
(c) thinning to leave a constant BT and thinning to periodically reduce the residual BT are about equal in yield, but in the latter example the BF volume in the seed cut was roughly 1Mbf greater.

This system of equations is quite comparable to the system presented in SO-156 by Farrar (1979) regarding total and merchantable cubic-foot volumes and is a considerable improvement regarding sawtimber volumes. Referring to Examples 1, 4, 5, and 6 in SO-156 and Example 1 and table 5 herein, we see that the total and merchantable cubic-foot volume values are, respectively, nearly equal. Differences occur in

Table 5.—*Current system predictions for tables 4, 5, and 6 in SO-156, SI 70*

Before-cut stand						After-cut stand						Cut stand					
BT	VIM	VOM	BS	VIS	VOS	BF	BT	VIM	VOM	BS	VIS	VOS	BF	BT	VIM	VOM	BS	VIS	VOS	BF
30	100	1933	2622	3.5	61*	80*	349*	70	1371	1847	3.5	61*	80*	349*	30	562	775	0	0	0	0
35	89	1977	2620	11	219	283	1287	70	1563	2061	11	219	283	1287	19	414	559	0	0	0	0
40	87	2108	2748	25	549	704	3309	70	1714	2225	24	527	676	3174	17	394	523	1	22	28	135
45	85	2209	2843	43	1023	1301	6257	70	1836	2355	40	952	1210	5811	15	373	488	3	71	91	446
50	83	2290	2917	58	1471	1858	9077	60	1669	2112	48	1218	1537	7483	23	621	805	10	253	321	1594
55	71	2062	2598	62	1658	2080	10261	30	888	1100	30	804	1005	4891	41	1174	1498	32	854	1075	5370
60	38	1142	1411	38	1064	1324	6515	0	0	0	0	0	0	0	38	1142	1411	38	1064	1324	6515
														Yield =	183	4680	6059	84	2264	2839	14060
														M.a.i. =	3.1	78	101	1.4	38	47	234

* = estimated by multiplying vol./sq.ft. of BS in smallest BS class (i.e., Appendix table 58) by 3.5

sawtimber volume comparisons because the present system allows the sawtimber basal area to be manipulated, within limits, whereas the former does not. The present system also features a total basal area projector that is more accurate for longer projection periods. Its separate sawtimber basal area projector also eliminates the minor inconsistency in estimating sawtimber volumes in thinning exercises at young ages encountered in the SO-156 system. By assuming BS1 = 3.5 at age 30 and simulating similar noncommercial periodic sawtimber cuts, the present system can be made to approximate Examples 5 and 6 illustrated for the SO-156 system (table 5).

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Appendix

	Page
Tables 1 through 14—VIT1, VIT2, and BT2	14
Tables 15 through 28—VOT1, VOT2, and BT2	42
Tables 29 through 42—VIM1, VIM2 and BT2	70
Tables 43 through 56—VOM1, VOM2 and BT2	98
Table 57—BS2	126
Table 58—VIS1 and VIS2	145
Table 59—VOS1 and VOS2	154
Table 60—BF1 and BF2	163

Table 1.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 20 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
20	20	220	256	299	348	406	20
	25	499	582	678	791	922	37
	30	861	1004	1171	1365	1591	56
	35	1263	1472	1716	2001	2332	74
	40	1668	1945	2267	2643	3082	91
	45	2057	2398	2796	3260	3800	106
	50	2419	2820	3288	3833	4469	119
25	25	274	319	372	434	506	20
	30	522	609	710	828	965	33
	35	830	967	1128	1315	1533	48
	40	1169	1363	1589	1852	2160	63
	45	1518	1770	2063	2406	2804	78
	50	1861	2170	2530	2949	3438	91
	55	2189	2552	2975	3468	4043	103
30	30	317	369	430	502	585	20
	35	540	629	733	855	997	31
	40	806	940	1096	1277	1489	43
	45	1099	1281	1494	1741	2030	56
	50	1403	1636	1907	2223	2592	68
	55	1707	1990	2320	2704	3153	80
	60	2002	2334	2721	3173	3699	91
35	35	352	410	478	557	649	20
	40	553	645	751	876	1021	29
	45	788	919	1071	1248	1455	40
	50	1045	1218	1420	1656	1930	50
	55	1313	1531	1784	2080	2425	61
	60	1584	1846	2152	2509	2926	72
	65	1851	2157	2515	2932	3419	81
40	40	380	443	517	602	702	20
	45	563	657	766	893	1041	28
	50	774	902	1051	1226	1429	37
	55	1002	1168	1362	1588	1851	46
	60	1241	1447	1687	1967	2293	56
	65	1484	1730	2017	2352	2742	65
	70	1726	2013	2347	2736	3189	74

Table 1.--Current and projected total cubic foot volumes, 3 b , (VII) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 20 square feet

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VII (cubic feet, 3 b./acre)					BT2
45	45	404	471	549	640	746	20
	50	572	667	778	907	1057	27
	55	762	888	1036	1207	1408	35
	60	967	1128	1315	1533	1787	43
	65	1183	1379	1608	1874	2185	52
	70	1403	1635	1907	2223	2591	60
	75	1624	1893	2207	2573	2999	68
50	50	424	494	576	672	783	20
	55	579	675	787	918	1070	26
	60	752	877	1023	1192	1390	33
	65	939	1095	1276	1488	1735	41
	70	1135	1323	1542	1798	2096	48
	75	1335	1556	1815	2116	2466	56
	80	1537	1792	2089	2436	2840	63
55	55	441	515	600	699	815	20
	60	585	682	796	928	1081	26
	65	745	868	1012	1180	1375	32
	70	915	1067	1244	1450	1691	39
	75	1094	1276	1487	1734	2021	45
	80	1278	1490	1737	2025	2361	52
60	60	456	532	620	723	843	20
	65	591	688	803	936	1091	25
	70	738	860	1003	1169	1363	31
	75	895	1044	1217	1418	1654	37
	80	1060	1236	1441	1680	1958	43
65	65	469	547	638	744	867	20
	70	595	694	809	943	1099	25
	75	732	853	995	1160	1352	30
	80	878	1023	1193	1391	1622	36
70	70	481	560	653	762	888	20
	75	599	698	814	949	1106	25
	80	727	848	988	1152	1343	29
75	75	491	572	667	778	907	20
	80	602	702	819	955	1113	24
80	80	500	583	679	792	923	20

Table 2.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 30 square feet

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
20	20	327	381	444	518	603	30
	25	686	799	932	1087	1267	51
	30	1114	1299	1515	1766	2059	73
	35	1560	1818	2120	2472	2881	92
	40	1989	2319	2704	3152	3675	109
	45	2387	2783	3244	3782	4409	123
	50	2746	3202	3733	4352	5074	135
25	25	407	474	553	644	751	30
	30	728	848	989	1153	1344	47
	35	1097	1279	1491	1739	2027	64
	40	1482	1728	2015	2349	2739	81
	45	1861	2169	2529	2949	3438	96
	50	2220	2588	3017	3517	4100	109
	55	2552	2975	3469	4044	4714	121
30	30	471	549	640	746	869	30
	35	759	885	1032	1203	1402	44
	40	1083	1263	1472	1717	2001	58
	45	1421	1657	1932	2252	2626	73
	50	1758	2049	2389	2785	3247	86
	55	2082	2427	2829	3299	3846	98
	60	2388	2784	3245	3783	4411	109
35	35	522	609	710	828	965	30
	40	784	913	1065	1242	1447	42
	45	1072	1250	1457	1699	1980	54
	50	1373	1600	1866	2175	2536	67
	55	1674	1952	2275	2652	3092	78
	60	1968	2294	2675	3118	3635	89
	65	2249	2622	3057	3564	4155	100
40	40	565	658	768	895	1043	30
	45	803	936	1091	1272	1483	40
	50	1063	1239	1444	1684	1963	51
	55	1333	1554	1812	2112	2462	62
	60	1605	1872	2182	2544	2966	73
	65	1873	2184	2546	2969	3461	83
	70	2133	2487	2899	3380	3940	92

Table 2.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 30 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
45	45	600	700	816	951	1109	30
	50	819	955	1113	1298	1513	39
	55	1055	1230	1434	1672	1949	49
	60	1300	1516	1767	2060	2402	58
	65	1548	1805	2104	2453	2860	68
	70	1794	2092	2439	2843	3314	77
	75	2034	2371	2764	3223	3757	86
50	50	630	735	857	999	1164	30
	55	832	970	1131	1319	1537	38
	60	1048	1222	1425	1661	1937	47
	65	1273	1484	1730	2017	2351	56
	70	1500	1749	2039	2377	2772	64
	75	1727	2013	2347	2736	3190	73
	80	1949	2273	2650	3089	3601	81
55	55	656	765	891	1039	1212	30
	60	843	983	1146	1336	1558	38
	65	1043	1216	1417	1652	1926	45
	70	1250	1457	1698	1980	2308	53
	75	1460	1702	1984	2313	2696	61
	80	1669	1946	2269	2645	3084	69
60	60	678	790	921	1074	1252	30
	65	853	994	1159	1351	1576	37
	70	1038	1210	1411	1645	1918	44
	75	1230	1434	1671	1949	2272	51
	80	1424	1661	1936	2257	2632	58
65	65	697	813	948	1105	1288	30
	70	861	1004	1171	1365	1591	36
	75	1034	1205	1405	1638	1910	43
	80	1212	1413	1648	1921	2240	50
70	70	714	833	971	1132	1319	30
	75	868	1012	1180	1376	1604	36
	80	1030	1201	1400	1633	1903	42
75	75	729	850	991	1156	1347	30
	80	875	1020	1189	1386	1616	35
80	80	743	866	1009	1177	1372	30

Table 3.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 40 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
20	20	433	504	588	686	799	40
	25	855	996	1161	1354	1579	64
	30	1328	1548	1805	2104	2453	87
	35	1798	2096	2444	2849	3322	106
	40	2237	2608	3040	3544	4132	123
	45	2633	3070	3579	4172	4864	136
	50	2985	3480	4057	4730	5514	147
25	25	539	628	732	853	995	40
	30	917	1069	1246	1453	1693	59
	35	1329	1549	1806	2106	2455	78
	40	1741	2030	2367	2759	3217	95
	45	2133	2487	2900	3380	3941	110
	50	2496	2910	3392	3955	4610	123
	55	2825	3293	3840	4476	5219	134
30	30	623	727	847	988	1151	40
	35	964	1123	1310	1527	1780	56
	40	1328	1548	1805	2104	2453	72
	45	1694	1975	2302	2684	3129	87
	50	2047	2386	2782	3243	3781	100
	55	2378	2772	3232	3768	4393	112
	60	2685	3130	3649	4254	4960	123
35	35	692	807	940	1096	1278	40
	40	1000	1166	1359	1585	1847	54
	45	1326	1546	1803	2102	2450	68
	50	1654	1929	2249	2622	3056	81
	55	1974	2301	2683	3128	3647	93
	60	2278	2656	3096	3610	4208	104
	65	2563	2988	3484	4062	4735	114
40	40	748	872	1017	1185	1382	40
	45	1029	1200	1399	1631	1901	52
	50	1324	1544	1800	2098	2446	64
	55	1622	1891	2204	2570	2996	76
	60	1913	2230	2600	3031	3534	87
	65	2193	2557	2981	3475	4052	97
	70	2459	2867	3342	3896	4542	106

Table 3.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 40 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
45	45	795	927	1081	1260	1469	40
	50	1053	1228	1432	1669	1946	51
	55	1322	1542	1797	2095	2443	62
	60	1594	1858	2166	2526	2945	72
	65	1861	2170	2530	2950	3439	82
	70	2120	2472	2882	3360	3917	91
	75	2368	2761	3219	3753	4375	100
50	50	835	973	1134	1323	1542	40
	55	1073	1251	1459	1701	1983	50
	60	1321	1540	1795	2093	2440	59
	65	1570	1831	2134	2488	2901	69
	70	1817	2119	2470	2880	3357	78
	75	2058	2399	2797	3261	3802	87
	80	2290	2669	3112	3628	4230	95
55	55	869	1013	1181	1376	1605	40
	60	1090	1271	1482	1727	2014	49
	65	1319	1538	1793	2090	2437	58
	70	1550	1807	2107	2456	2864	66
	75	1779	2074	2418	2819	3287	75
	80	2004	2336	2723	3175	3701	83
60	60	898	1047	1220	1423	1659	40
	65	1105	1288	1501	1750	2041	48
	70	1318	1536	1791	2088	2434	56
	75	1532	1787	2083	2428	2831	64
	80	1746	2036	2373	2767	3226	72
65	65	923	1077	1255	1463	1706	40
	70	1117	1302	1518	1770	2064	47
	75	1316	1534	1789	2086	2431	55
	80	1517	1769	2062	2404	2803	62
70	70	946	1103	1286	1499	1748	40
	75	1128	1315	1533	1788	2084	47
	80	1315	1533	1787	2084	2429	54
75	75	966	1126	1313	1531	1784	40
	80	1138	1327	1547	1803	2102	46
80	80	984	1147	1337	1559	1817	40

Table 4 --Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 50 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
20	20	538	627	731	853	994	50
	25	1010	1178	1373	1601	1867	76
	30	1515	1766	2059	2401	2799	99
	35	1999	2330	2717	3167	3693	119
	40	2439	2844	3315	3865	4506	134
	45	2830	3299	3846	4484	5228	147
	50	3173	3699	4312	5027	5861	157
25	25	670	781	910	1061	1237	50
	30	1094	1275	1486	1733	2020	71
	35	1536	1791	2088	2434	2838	91
	40	1964	2290	2670	3112	3628	107
	45	2361	2753	3209	3742	4362	122
	50	2721	3173	3699	4312	5028	134
	55	3044	3549	4138	4824	5624	144
30	30	775	904	1053	1228	1432	50
	35	1156	1348	1572	1833	2136	68
	40	1550	1807	2106	2455	2863	84
	45	1932	2253	2627	3062	3570	99
	50	2293	2673	3116	3633	4236	113
	55	2625	3060	3568	4159	4849	124
	60	2928	3413	3979	4639	5408	134
35	35	860	1003	1169	1363	1589	50
	40	1206	1406	1639	1911	2228	65
	45	1559	1818	2119	2470	2880	80
	50	1905	2221	2589	3018	3519	93
	55	2233	2604	3036	3539	4126	105
	60	2541	2962	3453	4026	4693	116
	65	2824	3293	3839	4475	5217	126
40	40	930	1085	1264	1474	1719	50
	45	1245	1452	1693	1974	2301	63
	50	1566	1826	2128	2481	2893	76
	55	1881	2193	2556	2980	3474	88
	60	2183	2544	2966	3458	4032	99
	65	2467	2876	3354	3910	4558	109
	70	2733	3187	3715	4331	5049	119

Table 4.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BTi) = 50 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
45	45	989	1153	1344	1567	1826	50
	50	1278	1490	1737	2025	2361	62
	55	1571	1832	2136	2490	2903	73
	60	1860	2168	2528	2947	3436	84
	65	2139	2493	2907	3389	3951	94
	70	2404	2802	3267	3809	4440	104
	75	2653	3093	3606	4204	4901	113
50	50	1038	1210	1411	1645	1918	50
	55	1305	1522	1774	2068	2411	61
	60	1575	1837	2141	2496	2910	71
	65	1842	2147	2503	2919	3403	81
	70	2100	2449	2855	3328	3880	91
	75	2348	2737	3191	3720	4337	99
	80	2583	3011	3510	4092	4771	107
55	55	1080	1259	1468	1712	1995	50
	60	1328	1549	1805	2105	2454	60
	65	1579	1840	2146	2502	2916	69
	70	1826	2129	2482	2894	3373	78
	75	2067	2410	2809	3275	3818	87
	80	2299	2680	3125	3643	4247	95
60	60	1117	1302	1518	1769	2063	50
	65	1348	1572	1832	2136	2491	59
	70	1581	1844	2149	2506	2921	68
	75	1812	2113	2463	2872	3348	76
	80	2038	2376	2770	3229	3764	84
65	65	1148	1339	1561	1820	2121	50
	70	1365	1592	1856	2164	2522	58
	75	1584	1846	2152	2509	2926	66
	80	1800	2098	2446	2852	3325	74
70	70	1176	1371	1599	1864	2173	50
	75	1380	1609	1876	2187	2550	58
	80	1586	1849	2155	2512	2929	65
75	75	1201	1400	1633	1903	2219	50
	80	1394	1625	1894	2209	2575	57
80	80	1223	1426	1663	1938	2260	50

Table 5.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 60 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq ft.
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
20	20	643	750	874	1019	1188	60
	25	1156	1348	1572	1832	2136	87
	30	1683	1962	2287	2666	3108	111
	35	2173	2533	2954	3443	4014	129
	40	2611	3044	3549	4137	4823	144
	45	2994	3491	4069	4744	5531	155
	50	3327	3879	4522	5272	6146	165
25	25	800	933	1088	1268	1479	60
	30	1261	1470	1714	1998	2329	82
	35	1724	2010	2344	2732	3185	102
	40	2161	2519	2937	3424	3992	118
	45	2558	2982	3477	4054	4726	132
	50	2913	3396	3959	4616	5381	144
	55	3227	3763	4387	5114	5962	153
30	30	926	1080	1259	1468	1711	60
	35	1340	1563	1822	2124	2476	79
	40	1754	2044	2384	2779	3240	96
	45	2146	2502	2917	3401	3965	111
	50	2508	2924	3409	3975	4634	123
	55	2837	3308	3857	4496	5242	134
	60	3134	3653	4259	4966	5789	144
35	35	1028	1198	1397	1629	1899	60
	40	1403	1636	1907	2223	2592	76
	45	1775	2070	2413	2813	3280	91
	50	2131	2485	2897	3377	3937	104
	55	2464	2872	3348	3904	4551	116
	60	2769	3229	3764	4388	5116	127
	65	3048	3554	4143	4830	5631	136
40	40	1112	1296	1511	1761	2054	60
	45	1454	1695	1976	2303	2685	74
	50	1792	2089	2436	2840	3311	87
	55	2117	2469	2878	3355	3912	100
	60	2424	2826	3294	3841	4478	111
	65	2709	3158	3682	4292	5004	120
	70	2971	3464	4039	4709	5489	129

Table 5.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BTi) = 60 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
45	45	1181	1377	1606	1872	2182	60
	50	1495	1743	2032	2369	2762	73
	55	1805	2105	2454	2861	3335	85
	60	2105	2454	2861	3335	3888	96
	65	2389	2785	3247	3785	4413	106
	70	2655	3095	3609	4207	4905	115
	75	2903	3384	3945	4600	5363	123
50	50	1240	1446	1686	1965	2291	60
	55	1530	1784	2080	2424	2826	71
	60	1816	2117	2469	2878	3355	82
	65	2093	2441	2845	3317	3867	92
	70	2358	2749	3205	3736	4356	102
	75	2607	3040	3544	4132	4817	111
	80	2842	3313	3862	4503	5249	118
55	55	1291	1505	1754	2045	2384	60
	60	1560	1818	2120	2471	2881	70
	65	1825	2128	2481	2892	3372	80
	70	2083	2429	2831	3301	3848	90
	75	2330	2717	3167	3693	4305	99
	80	2565	2991	3487	4065	4739	107
60	60	1334	1556	1813	2114	2465	60
	65	1585	1848	2154	2512	2928	70
	70	1833	2137	2491	2904	3386	79
	75	2074	2418	2819	3286	3831	87
	80	2306	2688	3134	3654	4260	96
65	65	1372	1600	1865	2174	2535	60
	70	1607	1874	2184	2547	2969	69
	75	1839	2144	2500	2914	3398	77
	80	2066	2408	2808	3273	3816	85
70	70	1406	1639	1911	2227	2597	60
	75	1627	1896	2211	2577	3005	68
	80	1845	2151	2507	2923	3408	76
75	75	1435	1673	1951	2274	2652	60
	80	1644	1916	2234	2605	3037	68
80	80	1462	1704	1987	2316	2700	60

Table 6.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longlea. pine in the East Gulf, initial basal area (BT1) = 70 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
20	20	747	871	1016	1184	1381	70
	25	1294	1509	1759	2051	2391	98
	30	1835	2139	2494	2908	3390	121
	35	2327	2713	3163	3688	4300	139
	40	2760	3218	3752	4374	5099	152
	45	3135	3655	4261	4967	5791	163
	50	3458	4031	4700	5479	6388	171
25	25	930	1085	1265	1474	1719	70
	30	1420	1656	1930	2250	2623	93
	35	1898	2213	2579	3007	3506	112
	40	2338	2726	3178	3705	4319	128
	45	2732	3185	3713	4329	5047	142
	50	3080	3590	4186	4880	5689	152
	55	3385	3946	4601	5364	6253	161
30	30	1077	1255	1463	1706	1989	70
	35	1517	1768	2061	2403	2802	89
	40	1944	2266	2642	3080	3590	106
	45	2341	2729	3181	3709	4324	121
	50	2701	3149	3671	4280	4990	133
	55	3025	3526	4111	4793	5587	143
	60	3313	3862	4503	5250	6120	152
35	35	1195	1393	1624	1894	2208	70
	40	1593	1857	2165	2524	2943	87
	45	1978	2306	2689	3135	3655	102
	50	2339	2727	3180	3707	4322	115
	55	2671	3114	3631	4233	4935	126
	60	2973	3466	4040	4710	5492	136
	65	3245	3783	4411	5142	5995	145
40	40	1292	1507	1756	2048	2387	70
	45	1655	1929	2249	2622	3057	85
	50	2006	2338	2726	3178	3705	98
	55	2336	2724	3176	3702	4316	110
	60	2643	3082	3593	4189	4883	121
	65	2925	3410	3976	4635	5404	130
	70	3183	3710	4326	5043	5879	139

able 6.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 70 square feet.

nitial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
45	45	1373	1601	1867	2176	2537	70
	50	1706	1989	2318	2703	3151	83
	55	2028	2364	2756	3213	3746	95
	60	2333	2720	3171	3696	4309	106
	65	2618	3052	3558	4149	4836	116
	70	2882	3360	3918	4567	5325	125
	75	3126	3644	4248	4953	5774	133
50	50	1442	1681	1960	2285	2664	70
	55	1748	2038	2377	2771	3230	82
	60	2046	2385	2781	3242	3779	93
	65	2329	2715	3165	3690	4302	103
	70	2595	3025	3527	4112	4794	112
	75	2844	3315	3865	4506	5253	121
	80	3074	3584	4179	4871	5679	128
55	55	1500	1749	2039	2378	2772	70
	60	1785	2081	2426	2828	3297	81
	65	2061	2403	2801	3266	3807	91
	70	2325	2710	3160	3684	4295	100
	75	2574	3001	3499	4079	4756	109
	80	2809	3275	3818	4451	5189	117
60	60	1551	1808	2108	2458	2865	70
	65	1816	2117	2469	2878	3355	80
	70	2074	2418	2819	3286	3831	89
	75	2321	2706	3155	3678	4288	98
	80	2556	2980	3474	4050	4721	106
65	65	1595	1860	2168	2528	2947	70
	70	1844	2149	2506	2921	3406	79
	75	2085	2431	2834	3304	3852	88
	80	2317	2701	3150	3672	4281	96
70	70	1634	1905	2221	2589	3019	70
	75	1867	2177	2538	2959	3450	79
	80	2095	2442	2847	3319	3870	87
75	75	1669	1945	2268	2644	3082	70
	80	1889	2202	2567	2993	3489	78
80	80	1699	1981	2310	2693	3139	70

Table 7.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 80 square feet.

Initial age (Years)	Final age	Site index					Projected basal area
		50	60	70	80	90	(sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
20	20	852	993	1157	1349	1573	80
	25	1425	1661	1937	2258	2633	108
	30	1975	2303	2685	3130	3649	130
	35	2466	2875	3352	3908	4556	147
	40	2892	3372	3931	4583	5343	160
	45	3258	3798	4428	5163	6019	169
	50	3571	4164	4854	5659	6598	177
25	25	1060	1236	1441	1680	1958	80
	30	1573	1833	2137	2492	2905	103
	35	2059	2401	2799	3263	3804	122
	40	2499	2914	3397	3960	4617	138
	45	2888	3366	3925	4576	5334	150
	50	3227	3762	4386	5114	5962	160
	55	3523	4107	4789	5583	6509	168
30	30	1227	1430	1667	1944	2266	80
	35	1686	1966	2292	2672	3116	100
	40	2122	2474	2884	3362	3920	116
	45	2519	2937	3424	3992	4654	130
	50	2876	3352	3908	4557	5312	142
	55	3192	3721	4338	5058	5896	152
	60	3472	4047	4718	5501	6413	160
35	35	1362	1587	1851	2157	2515	80
	40	1777	2071	2415	2815	3282	97
	45	2170	2530	2949	3439	4009	112
	50	2532	2952	3442	4013	4678	125
	55	2861	3335	3888	4533	5285	136
	60	3156	3680	4290	5001	5831	145
	65	3421	3988	4649	5420	6319	153
40	40	1472	1717	2001	2333	2720	80
	45	1850	2157	2515	2932	3418	95
	50	2208	2575	3002	3499	4080	108
	55	2541	2962	3454	4026	4694	120
	60	2845	3317	3867	4509	5256	130
	65	3122	3640	4243	4947	5768	139
	70	3373	3932	4584	5344	6230	147

Table 7.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 80 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
45	45	1565	1824	2127	2479	2891	80
	50	1911	2228	2597	3028	3530	93
	55	2240	2611	3044	3549	4137	105
	60	2547	2969	3461	4035	4705	116
	65	2830	3300	3847	4485	5229	126
	70	3090	3603	4200	4897	5709	134
	75	3328	3880	4523	5273	6147	142
50	50	1643	1915	2233	2603	3035	80
	55	1962	2287	2666	3108	3624	92
	60	2266	2641	3079	3590	4185	103
	65	2551	2974	3467	4042	4712	113
	70	2816	3283	3827	4462	5202	122
	75	3061	3568	4160	4850	5655	130
	80	3286	3831	4467	5207	6071	138
55	55	1709	1993	2324	2709	3158	80
	60	2005	2338	2725	3177	3704	91
	65	2287	2667	3109	3625	4226	101
	70	2554	2977	3471	4046	4717	111
	75	2803	3267	3809	4441	5177	119
	80	3034	3537	4124	4808	5605	127
60	60	1767	2060	2402	2800	3265	80
	65	2043	2381	2776	3237	3773	90
	70	2306	2689	3134	3654	4260	100
	75	2556	2979	3474	4050	4721	108
	80	2790	3253	3792	4421	5154	116
65	65	1818	2119	2470	2880	3358	80
	70	2075	2419	2821	3288	3834	89
	75	2322	2707	3156	3680	4290	98
	80	2557	2981	3475	4052	4724	106
70	70	1862	2171	2531	2950	3439	80
	75	2104	2453	2859	3334	3887	89
	80	2336	2724	3176	3702	4316	97
75	75	1901	2216	2584	3012	3512	80
	80	2129	2482	2894	3374	3933	88
80	80	1936	2257	2631	3068	3577	80

Table 8.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 90 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
20	20	955	1114	1298	1514	1765	90
	25	1550	1807	2107	2456	2863	118
	30	2105	2454	2861	3336	3889	139
	35	2593	3023	3524	4108	4790	155
	40	3011	3510	4092	4771	5562	166
	45	3367	3926	4577	5336	6221	175
	50	3672	4280	4990	5818	6783	182
25	25	1189	1387	1616	1885	2197	90
	30	1719	2004	2337	2724	3176	113
	35	2211	2577	3005	3503	4084	131
	40	2648	3087	3598	4195	4891	146
	45	3029	3531	4117	4799	5595	157
	50	3359	3917	4566	5323	6206	166
	55	3646	4251	4956	5778	6736	174
30	30	1376	1604	1871	2181	2542	90
	35	1851	2158	2515	2933	3419	110
	40	2290	2670	3113	3629	4231	126
	45	2685	3131	3650	4255	4961	139
	50	3035	3539	4125	4810	5607	150
	55	3343	3898	4544	5298	6176	159
	60	3614	4213	4912	5727	6676	166
35	35	1528	1781	2076	2421	2822	90
	40	1955	2279	2657	3098	3612	107
	45	2352	2742	3197	3727	4346	121
	50	2713	3162	3687	4298	5011	134
	55	3036	3539	4126	4810	5608	144
	60	3324	3875	4517	5266	6140	153
	65	3580	4173	4865	5672	6613	160
40	40	1652	1926	2245	2618	3052	90
	45	2040	2379	2773	3233	3769	105
	50	2402	2800	3265	3806	4437	118
	55	2733	3186	3715	4331	5049	129
	60	3033	3536	4122	4806	5603	139
	65	3303	3850	4489	5234	6101	147
	70	3545	4133	4819	5618	6550	155

able 8.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 90 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
45	45	1755	2047	2386	2782	3243	90
	50	2111	2461	2869	3345	3899	103
	55	2443	2848	3320	3871	4513	115
	60	2749	3205	3736	4356	5078	126
	65	3028	3531	4116	4799	5594	135
	70	3282	3827	4461	5201	6064	143
	75	3512	4095	4774	5566	6489	150
50	50	1843	2149	2505	2920	3405	90
	55	2170	2530	2950	3439	4009	102
	60	2477	2888	3367	3925	4576	113
	65	2761	3219	3753	4376	5101	123
	70	3023	3524	4109	4790	5585	131
	75	3263	3804	4434	5170	6027	139
	80	3481	4059	4732	5517	6431	146
55	55	1918	2236	2607	3039	3543	90
	60	2221	2589	3018	3519	4103	101
	65	2506	2921	3406	3971	4629	111
	70	2771	3231	3767	4392	5120	120
	75	3017	3518	4101	4781	5574	128
	80	3244	3782	4409	5140	5993	136
60	60	1983	2311	2695	3142	3663	90
	65	2264	2640	3078	3588	4183	100
	70	2531	2950	3440	4010	4675	110
	75	2780	3241	3778	4405	5135	118
	80	3012	3511	4093	4772	5563	126
65	65	2039	2377	2772	3231	3767	90
	70	2303	2684	3130	3649	4254	99
	75	2552	2975	3469	4044	4715	108
	80	2787	3249	3788	4416	5148	116
70	70	2089	2435	2839	3310	3859	90
	75	2336	2724	3175	3702	4316	99
	80	2571	2997	3494	4074	4749	107
75	75	2133	2487	2899	3380	3940	90
	80	2366	2758	3216	3749	4371	98
80	80	2172	2532	2952	3442	4013	90

Table 9.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 100 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
20	20	1059	1234	1439	1678	1956	100
	25	1670	1947	2270	2646	3085	127
	30	2227	2596	3027	3529	4114	147
	35	2709	3158	3682	4292	5004	162
	40	3119	3636	4239	4942	5761	172
	45	3466	4041	4711	5492	6403	181
	50	3761	4385	5112	5959	6948	187
25	25	1318	1537	1792	2089	2435	100
	30	1861	2170	2529	2949	3438	123
	35	2354	2744	3199	3729	4348	140
	40	2785	3247	3785	4413	5145	154
	45	3158	3682	4293	5004	5834	164
	50	3480	4057	4729	5514	6428	172
	55	3757	4380	5106	5953	6940	179
30	30	1525	1778	2073	2417	2818	100
	35	2010	2343	2732	3185	3713	119
	40	2450	2856	3330	3882	4526	135
	45	2840	3311	3861	4501	5247	147
	50	3183	3710	4326	5043	5880	157
	55	3482	4059	4732	5517	6432	166
	60	3743	4364	5088	5931	6915	172
35	35	1693	1974	2301	2683	3128	100
	40	2129	2482	2893	3373	3933	117
	45	2526	2945	3434	4003	4667	131
	50	2882	3360	3917	4567	5325	142
	55	3198	3729	4347	5068	5908	152
	60	3478	4054	4727	5510	6424	160
	65	3725	4342	5062	5902	6881	167
40	40	1831	2135	2489	2901	3382	100
	45	2226	2595	3025	3527	4112	115
	50	2588	3017	3517	4100	4780	127
	55	2915	3398	3962	4619	5385	138
	60	3208	3740	4360	5083	5926	147
	65	3470	4046	4716	5499	6410	155
	70	3704	4318	5035	5869	6843	162

Table 9.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 100 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
45	45	1946	2268	2645	3083	3595	100
	50	2306	2689	3135	3655	4261	113
	55	2638	3076	3586	4181	4874	125
	60	2941	3428	3997	4660	5433	135
	65	3214	3747	4369	5093	5938	143
	70	3461	4035	4704	5484	6394	151
	75	3683	4294	5006	5836	6804	157
50	50	2043	2382	2777	3237	3774	100
	55	2374	2768	3227	3762	4386	112
	60	2681	3126	3644	4248	4953	123
	65	2962	3453	4026	4694	5472	132
	70	3218	3752	4374	5100	5945	140
	75	3451	4023	4691	5468	6375	147
	80	3662	4270	4978	5803	6766	154
55	55	2126	2478	2889	3369	3927	100
	60	2432	2836	3306	3854	4493	111
	65	2717	3168	3693	4306	5020	121
	70	2980	3474	4050	4722	5505	129
	75	3221	3755	4377	5103	5950	137
	80	3441	4012	4677	5452	6357	144
60	60	2198	2562	2987	3482	4060	100
	65	2482	2894	3374	3934	4586	110
	70	2748	3204	3735	4355	5077	119
	75	2995	3491	4070	4745	5532	127
	80	3222	3756	4379	5105	5952	135
65	65	2260	2635	3072	3581	4175	100
	70	2526	2945	3434	4003	4667	109
	75	2775	3236	3772	4398	5127	118
	80	3007	3506	4087	4765	5556	126
70	70	2315	2699	3147	3669	4277	100
	75	2565	2990	3486	4064	4738	109
	80	2799	3263	3805	4436	5171	117
75	75	2364	2756	3213	3746	4367	100
	80	2599	3030	3532	4118	4801	108
80	80	2408	2807	3272	3815	4448	100

Table 10 --Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 110 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
20	20	1162	1355	1580	1842	2147	110
	25	1785	2081	2426	2829	3298	136
	30	2341	2729	3182	3710	4325	155
	35	2816	3283	3828	4463	5203	168
	40	3217	3751	4373	5098	5943	178
	45	3555	4145	4832	5633	6568	185
	50	3842	4479	5221	6087	7097	191
25	25	1447	1687	1966	2293	2673	110
	30	1998	2329	2716	3166	3691	132
	35	2489	2902	3383	3944	4598	148
	40	2914	3397	3960	4617	5382	161
	45	3278	3821	4455	5194	6055	171
	50	3589	4185	4879	5688	6631	178
	55	3858	4497	5243	6113	7126	184
30	30	1674	1952	2276	2653	3093	110
	35	2165	2524	2942	3430	3999	129
	40	2603	3034	3537	4124	4808	143
	45	2986	3481	4059	4732	5517	155
	50	3320	3870	4512	5260	6133	164
	55	3609	4208	4906	5719	6668	172
	60	3861	4502	5248	6119	7133	178
35	35	1858	2167	2526	2945	3433	110
	40	2298	2679	3123	3641	4245	126
	45	2693	3140	3660	4267	4975	139
	50	3043	3547	4135	4821	5621	150
	55	3350	3906	4553	5308	6189	159
	60	3620	4221	4921	5737	6688	167
	65	3858	4498	5244	6114	7127	173
40	40	2010	2343	2731	3184	3712	110
	45	2407	2806	3272	3814	4447	124
	50	2766	3225	3760	4384	5110	136
	55	3087	3599	4196	4892	5703	147
	60	3373	3932	4584	5344	6231	155
	65	3626	4227	4928	5746	6698	162
	70	3851	4490	5234	6102	7114	168

Table 10.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 110 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
45	45	2136	2490	2903	3384	3945	110
	50	2498	2912	3395	3958	4615	123
	55	2827	3296	3843	4480	5223	134
	60	3124	3642	4246	4950	5771	143
	65	3390	3952	4607	5372	6262	151
	70	3628	4230	4931	5749	6703	158
	75	3842	4479	5222	6087	7097	164
50	50	2242	2614	3047	3553	4142	110
	55	2575	3002	3499	4080	4756	122
	60	2878	3356	3912	4561	5318	132
	65	3154	3677	4287	4998	5827	141
	70	3403	3968	4626	5393	6287	148
	75	3628	4230	4931	5749	6702	155
	80	3831	4467	5207	6071	7078	161
55	55	2333	2720	3171	3697	4310	110
	60	2640	3078	3589	4184	4877	121
	65	2922	3407	3972	4630	5398	130
	70	3180	3707	4322	5038	5874	138
	75	3414	3980	4640	5409	6307	146
	80	3627	4228	4929	5747	6700	152
60	60	2412	2812	3278	3822	4456	110
	65	2697	3144	3666	4274	4982	120
	70	2960	3451	4023	4690	5468	129
	75	3201	3732	4351	5073	5914	136
	80	3422	3990	4652	5423	6322	143
65	65	2481	2892	3372	3931	4583	110
	70	2747	3202	3733	4352	5074	119
	75	2993	3489	4068	4742	5529	127
	80	3220	3754	4377	5103	5949	135
70	70	2541	2963	3454	4027	4694	110
	75	2790	3253	3792	4421	5154	118
	80	3022	3523	4107	4788	5582	126
75	75	2595	3025	3527	4111	4793	110
	80	2829	3298	3845	4483	5226	118
80	80	2642	3081	3592	4187	4882	110

Table 11.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 120 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
20	20	1265	1475	1720	2005	2337	120
	25	1896	2211	2577	3005	3503	145
	30	2449	2855	3329	3881	4524	162
	35	2916	3400	3964	4621	5388	174
	40	3308	3857	4496	5242	6111	183
	45	3637	4240	4943	5763	6719	190
	50	3915	4564	5321	6204	7232	195
25	25	1575	1836	2141	2496	2910	120
	30	2131	2484	2896	3377	3937	141
	35	2618	3052	3558	4148	4836	156
	40	3034	3537	4124	4808	5605	168
	45	3389	3951	4606	5369	6260	176
	50	3691	4303	5016	5848	6818	183
	55	3950	4605	5368	6259	7297	189
30	30	1823	2125	2478	2888	3367	120
	35	2315	2699	3147	3669	4277	138
	40	2749	3204	3736	4355	5078	152
	45	3124	3642	4246	4950	5771	162
	50	3448	4020	4686	5463	6369	171
	55	3728	4346	5067	5907	6886	178
	60	3970	4629	5396	6291	7335	183
35	35	2023	2359	2750	3206	3738	120
	40	2463	2872	3348	3903	4551	135
	45	2853	3326	3878	4521	5271	148
	50	3195	3725	4342	5062	5902	158
	55	3493	4072	4748	5535	6453	166
	60	3754	4376	5102	5948	6934	173
	65	3982	4642	5412	6310	7356	179
40	40	2188	2551	2974	3467	4042	120
	45	2585	3013	3513	4096	4775	134
	50	2939	3426	3994	4657	5429	145
	55	3252	3791	4420	5153	6007	155
	60	3528	4113	4795	5591	6518	162
	65	3772	4398	5127	5977	6968	169
	70	3988	4649	5420	6319	7367	174

Table 11.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 120 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
45	45	2325	2711	3160	3684	4295	120
	50	2686	3131	3651	4256	4962	132
	55	3010	3509	4091	4769	5560	143
	60	3299	3846	4484	5227	6094	152
	65	3556	4146	4834	5635	6570	159
	70	3786	4413	5145	5998	6993	165
	75	3990	4652	5423	6322	7371	171
50	50	2441	2846	3318	3868	4510	120
	55	2771	3231	3767	4392	5120	131
	60	3070	3579	4173	4865	5671	141
	65	3338	3892	4537	5290	6167	149
	70	3579	4173	4865	5672	6612	156
	75	3795	4425	5159	6014	7012	162
	80	3990	4651	5423	6322	7370	168
55	55	2540	2962	3453	4025	4693	120
	60	2845	3317	3867	4508	5255	130
	65	3121	3639	4243	4946	5766	139
	70	3372	3931	4583	5343	6229	147
	75	3598	4195	4891	5702	6647	154
	80	3803	4433	5169	6026	7025	160
60	60	2626	3061	3569	4161	4851	120
	65	2908	3390	3953	4608	5372	129
	70	3166	3691	4303	5017	5849	138
	75	3401	3965	4622	5389	6282	145
	80	3614	4214	4912	5727	6677	152
65	65	2701	3149	3671	4280	4989	120
	70	2964	3455	4028	4696	5475	129
	75	3205	3736	4356	5078	5921	137
	80	3426	3994	4656	5428	6329	143
70	70	2767	3225	3760	4384	5111	120
	75	3013	3512	4095	4774	5565	128
	80	3239	3776	4403	5133	5984	135
75	75	2825	3293	3839	4476	5219	120
	80	3056	3563	4154	4842	5645	128
80	80	2877	3354	3910	4559	5315	120

Table 12.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 130 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
20	20	1368	1595	1860	2168	2528	130
	25	2004	2336	2724	3175	3702	154
	30	2551	2975	3468	4043	4713	169
	35	3010	3509	4091	4770	5561	180
	40	3392	3955	4611	5375	6267	188
	45	3712	4328	5046	5882	6858	194
	50	3982	4643	5413	6310	7357	198
25	25	1703	1986	2315	2699	3147	130
	30	2260	2635	3072	3582	4176	150
	35	2740	3195	3725	4342	5063	164
	40	3148	3670	4278	4988	5815	174
	45	3492	4071	4747	5534	6451	182
	50	3785	4412	5144	5997	6992	188
	55	4035	4704	5484	6394	7454	193
30	30	1971	2298	2679	3123	3641	130
	35	2462	2871	3347	3902	4549	147
	40	2889	3368	3926	4577	5336	159
	45	3254	3794	4423	5157	6012	169
	50	3568	4160	4850	5654	6592	177
	55	3838	4475	5217	6082	7090	183
	60	4071	4747	5534	6452	7522	188
35	35	2188	2551	2974	3467	4042	130
	40	2625	3061	3568	4160	4850	145
	45	3008	3506	4088	4766	5556	156
	50	3340	3894	4539	5292	6170	165
	55	3628	4229	4931	5749	6702	173
	60	3878	4522	5272	6146	7165	179
	65	4097	4777	5569	6493	7569	184
40	40	2366	2758	3215	3749	4370	130
	45	2759	3216	3750	4372	5097	143
	50	3105	3620	4221	4921	5737	154
	55	3409	3975	4634	5402	6298	162
	60	3676	4285	4996	5824	6790	169
	65	3910	4558	5314	6195	7223	175
	70	4116	4798	5594	6522	7604	180

Table 12.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 130 square feet

Initial age (Years)	Final age	Site index 50	60	70	80	90	Projected basal area (sq ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
45	45	2514	2931	3417	3984	4645	130
	50	2871	3347	3902	4549	5303	142
	55	3187	3716	4332	5050	5888	151
	60	3467	4042	4712	5494	6405	159
	65	3715	4331	5049	5886	6863	166
	70	3934	4587	5347	6234	7268	172
	75	4129	4814	5612	6543	7628	177
50	50	2640	3077	3588	4183	4876	130
	55	2965	3457	4030	4698	5478	141
	60	3256	3796	4426	5160	6015	150
	65	3516	4099	4779	5571	6495	157
	70	3747	4369	5093	5938	6923	164
	75	3954	4610	5374	6266	7305	169
	80	4139	4825	5626	6559	7646	174
55	55	2747	3202	3733	4353	5074	130
	60	3046	3551	4140	4827	5627	140
	65	3316	3865	4506	5254	6125	148
	70	3558	4147	4835	5637	6572	155
	75	3775	4401	5131	5982	6973	161
	80	3970	4629	5396	6291	7334	167
60	60	2840	3310	3859	4499	5246	130
	65	3116	3633	4236	4938	5757	139
	70	3367	3925	4576	5335	6220	147
	75	3594	4190	4884	5694	6639	154
	80	3798	4428	5163	6019	7017	159
65	65	2920	3405	3969	4628	5395	130
	70	3178	3705	4319	5036	5871	138
	75	3412	3978	4638	5407	6304	146
	80	3625	4226	4927	5744	6697	152
70	70	2992	3488	4066	4740	5526	130
	75	3232	3768	4393	5121	5971	138
	80	3452	4024	4692	5470	6377	145
75	75	3055	3561	4152	4840	5643	130
	80	3280	3824	4458	5198	6060	137
80	80	3111	3627	4228	4929	5747	130

Table 13.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 140 square feet.

Initial age (Years)	Final age	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
20	20	1471	1715	1999	2331	2717	140
	25	2108	2458	2865	3340	3894	162
	30	2649	3088	3600	4197	4893	176
	35	3098	3612	4211	4909	5723	186
	40	3471	4046	4717	5500	6412	192
	45	3782	4409	5141	5993	6987	197
	50	4045	4715	5497	6409	7472	201
25	25	1831	2135	2489	2902	3383	140
	30	2386	2782	3243	3781	4408	158
	35	2858	3332	3885	4529	5280	171
	40	3255	3795	4424	5158	6014	180
	45	3589	4185	4879	5688	6631	187
	50	3872	4515	5263	6136	7154	192
	55	4114	4796	5592	6519	7600	197
30	30	2119	2470	2880	3358	3915	140
	35	2606	3038	3542	4129	4814	155
	40	3023	3525	4109	4791	5585	167
	45	3379	3939	4592	5354	6242	176
	50	3682	4292	5004	5834	6802	183
	55	3942	4595	5357	6246	7282	188
	60	4166	4857	5662	6601	7696	192
35	35	2352	2742	3197	3727	4345	140
	40	2784	3245	3783	4411	5142	154
	45	3157	3680	4291	5002	5832	164
	50	3478	4055	4728	5512	6426	172
	55	3756	4379	5105	5951	6938	179
	60	3996	4659	5431	6332	7382	184
	65	4205	4903	5716	6664	7769	189
40	40	2543	2965	3457	4030	4699	140
	45	2930	3416	3982	4643	5412	152
	50	3267	3809	4440	5177	6035	162
	55	3560	4151	4839	5641	6577	170
	60	3816	4449	5187	6047	7049	176
	65	4040	4710	5491	6401	7463	181
	70	4236	4939	5758	6713	7826	186

Table 13.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 140 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
45	45	2703	3151	3674	4283	4993	140
	50	3052	3558	4148	4836	5638	151
	55	3359	3916	4566	5323	6205	160
	60	3629	4231	4932	5750	6704	167
	65	3866	4507	5255	6126	7142	173
	70	4075	4751	5539	6458	7529	178
	75	4261	4967	5791	6751	7871	183
50	50	2838	3308	3857	4497	5242	140
	55	3156	3679	4289	5000	5830	150
	60	3437	4008	4672	5447	6350	158
	65	3687	4298	5011	5842	6811	165
	70	3908	4556	5312	6193	7220	171
	75	4105	4786	5579	6505	7583	176
	80	4280	4990	5818	6783	7908	180
55	55	2953	3443	4014	4679	5455	140
	60	3245	3783	4410	5141	5994	149
	65	3505	4086	4764	5554	6475	157
	70	3737	4357	5079	5922	6904	163
	75	3944	4598	5361	6250	7287	169
	80	4130	4815	5613	6544	7629	174
60	60	3053	3559	4149	4837	5639	140
	65	3322	3873	4515	5264	6137	148
	70	3564	4154	4843	5647	6583	155
	75	3780	4407	5138	5990	6984	162
	80	3976	4635	5403	6300	7344	167
65	65	3140	3660	4267	4975	5800	140
	70	3389	3951	4607	5371	6261	148
	75	3615	4214	4913	5728	6678	154
	80	3819	4452	5190	6051	7054	160
70	70	3216	3749	4371	5096	5941	140
	75	3449	4021	4688	5465	6372	147
	80	3660	4267	4975	5800	6762	154
75	75	3284	3829	4463	5204	6067	140
	80	3502	4083	4760	5549	6469	147
80	80	3344	3899	4546	5299	6178	140

Table 14.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 150 square feet

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
20	20	1573	1834	2139	2493	2907	150
	25	2209	2576	3003	3501	4081	170
	30	2742	3196	3727	4345	5065	182
	35	3181	3709	4324	5041	5877	191
	40	3544	4132	4817	5616	6548	197
	45	3847	4485	5229	6096	7107	201
	50	4102	4783	5576	6500	7578	204
25	25	1959	2284	2662	3104	3619	150
	30	2509	2925	3410	3975	4635	166
	35	2971	3464	4038	4708	5489	178
	40	3357	3914	4563	5320	6202	186
	45	3681	4292	5003	5833	6800	192
	50	3955	4610	5375	6266	7306	197
	55	4188	4882	5692	6636	7736	200
30	30	2267	2643	3081	3592	4188	150
	35	2747	3202	3733	4352	5074	164
	40	3153	3676	4286	4997	5825	174
	45	3497	4077	4753	5542	6461	182
	50	3789	4418	5150	6005	7000	188
	55	4039	4709	5490	6400	7462	193
	60	4254	4960	5782	6741	7859	197
35	35	2516	2933	3420	3987	4648	150
	40	2939	3426	3995	4657	5430	162
	45	3301	3849	4487	5231	6099	172
	50	3611	4210	4908	5722	6671	179
	55	3877	4520	5270	6144	7163	185
	60	4107	4788	5582	6508	7587	190
	65	4307	5021	5854	6825	7957	194
40	40	2721	3172	3698	4311	5026	150
	45	3098	3612	4210	4909	5723	161
	50	3424	3991	4653	5425	6325	170
	55	3705	4320	5036	5871	6845	177
	60	3950	4605	5369	6259	7297	182
	65	4163	4853	5658	6597	7691	187
	70	4350	5071	5912	6893	8036	191

ble 14.--Current and projected total cubic foot volumes, i.b., (VIT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 150 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIT (cubic feet,i.b.,/acre)					BT2
45	45	2891	3371	3930	4582	5341	150
	50	3231	3766	4391	5119	5968	160
	55	3527	4111	4793	5588	6515	168
	60	3785	4412	5144	5997	6992	174
	65	4011	4676	5451	6355	7409	180
	70	4210	4908	5722	6670	7777	184
	75	4385	5112	5960	6949	8101	188
50	50	3036	3539	4126	4810	5608	150
	55	3344	3898	4544	5298	6177	159
	60	3614	4214	4912	5727	6677	166
	65	3852	4491	5236	6105	7117	173
	70	4063	4737	5522	6438	7505	178
	75	4249	4954	5775	6733	7849	182
	80	4415	5147	6000	6995	8156	186
55	55	3159	3683	4294	5006	5836	150
	60	3440	4011	4676	5452	6356	158
	65	3690	4302	5015	5847	6816	165
	70	3911	4560	5316	6197	7225	171
	75	4107	4789	5583	6509	7588	176
	80	4283	4993	5821	6786	7912	180
60	60	3266	3807	4438	5174	6033	150
	65	3525	4109	4791	5585	6511	158
	70	3756	4379	5105	5951	6938	164
	75	3962	4619	5385	6278	7319	170
	80	4146	4834	5636	6570	7660	174
65	65	3359	3915	4565	5322	6204	150
	70	3598	4195	4891	5702	6648	157
	75	3814	4446	5183	6043	7045	163
	80	4007	4671	5446	6349	7402	168
70	70	3440	4011	4676	5451	6356	150
	75	3663	4271	4979	5805	6768	157
	80	3865	4506	5253	6124	7140	162
75	75	3513	4095	4775	5566	6490	150
	80	3721	4339	5058	5897	6875	156
80	80	3578	4171	4863	5669	6609	150

Table 15.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 20 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
20	20	323	370	423	483	552	20
	25	711	813	929	1062	1214	37
	30	1201	1373	1570	1795	2051	56
	35	1734	1982	2266	2590	2961	74
	40	2264	2588	2959	3382	3866	91
	45	2767	3163	3615	4132	4724	106
	50	3229	3691	4219	4823	5513	119
25	25	385	440	503	575	657	20
	30	721	824	942	1077	1231	33
	35	1130	1291	1476	1687	1929	48
	40	1575	1801	2058	2353	2690	63
	45	2029	2319	2651	3030	3464	78
	50	2471	2824	3229	3691	4219	91
	55	2890	3303	3776	4316	4934	103
30	30	433	495	565	646	739	20
	35	728	832	951	1088	1243	31
	40	1078	1232	1408	1610	1840	43
	45	1459	1668	1906	2179	2491	56
	50	1852	2117	2420	2766	3162	68
	55	2242	2562	2929	3348	3827	80
	60	2619	2994	3422	3912	4472	91
35	35	470	537	614	702	803	20
	40	734	838	958	1096	1252	29
	45	1039	1187	1357	1552	1774	40
	50	1371	1567	1791	2047	2340	50
	55	1715	1961	2241	2562	2928	61
	60	2061	2357	2694	3079	3520	72
	65	2402	2745	3138	3587	4101	81
40	40	500	572	654	747	854	20
	45	738	843	964	1102	1260	28
	50	1008	1153	1318	1506	1722	37
	55	1302	1488	1701	1944	2223	46
	60	1607	1837	2100	2401	2745	56
	65	1917	2192	2506	2864	3274	65
	70	2225	2544	2908	3324	3800	74

Table 15.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 20 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
45	45	525	600	686	785	897	20
	50	741	847	969	1107	1266	27
	55	984	1125	1286	1470	1681	35
	60	1247	1425	1629	1862	2129	43
	65	1521	1738	1987	2272	2597	52
	70	1800	2058	2353	2689	3074	60
	75	2080	2378	2718	3107	3552	68
50	50	546	624	714	816	932	20
	55	744	851	972	1111	1270	26
	60	965	1103	1260	1441	1647	33
	65	1202	1374	1570	1795	2052	41
	70	1450	1657	1894	2166	2475	48
	75	1704	1948	2226	2545	2909	56
	80	1960	2240	2561	2927	3346	63
55	55	564	644	737	842	962	20
	60	746	853	975	1115	1275	26
	65	948	1084	1239	1416	1619	32
	70	1164	1331	1522	1739	1988	39
	75	1391	1590	1817	2077	2374	45
	80	1623	1855	2121	2424	2771	52
60	60	579	662	756	865	988	20
	65	749	856	978	1118	1278	25
	70	934	1068	1221	1396	1596	31
	75	1133	1295	1480	1692	1935	37
	80	1341	1533	1752	2003	2289	43
65	65	592	677	773	884	1011	20
	70	750	858	980	1121	1281	25
	75	923	1055	1206	1378	1575	30
	80	1106	1264	1445	1652	1889	36
70	70	603	690	788	901	1030	20
	75	752	859	982	1123	1284	25
	80	912	1043	1192	1363	1558	29
75	75	614	701	802	916	1048	20
	80	753	861	984	1125	1286	24
80	80	623	712	813	930	1063	20

Table 16.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 30 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
20	20	484	554	633	724	827	30
	25	983	1124	1285	1469	1679	51
	30	1562	1786	2042	2334	2668	73
	35	2151	2459	2811	3214	3674	92
	40	2710	3098	3541	4048	4627	109
	45	3220	3680	4207	4809	5497	123
	50	3675	4201	4803	5490	6276	135
25	25	577	659	754	862	985	30
	30	1011	1156	1322	1511	1727	47
	35	1503	1718	1963	2244	2565	64
	40	2007	2295	2623	2998	3427	81
	45	2497	2855	3263	3730	4264	96
	50	2957	3380	3864	4417	5049	109
	55	3380	3864	4417	5049	5771	121
30	30	648	741	847	968	1107	30
	35	1032	1179	1348	1541	1761	44
	40	1457	1666	1904	2177	2488	58
	45	1897	2168	2479	2834	3239	73
	50	2331	2664	3045	3481	3979	86
	55	2745	3138	3587	4101	4688	98
	60	3135	3583	4096	4682	5352	109
35	35	704	805	920	1052	1203	30
	40	1047	1197	1368	1564	1788	42
	45	1422	1626	1858	2124	2428	54
	50	1811	2070	2366	2705	3092	67
	55	2198	2512	2872	3283	3753	78
	60	2573	2942	3362	3844	4394	89
	65	2931	3350	3830	4378	5005	100
40	40	750	857	980	1120	1280	30
	45	1059	1211	1384	1582	1808	40
	50	1394	1594	1822	2083	2381	51
	55	1742	1991	2276	2602	2974	62
	60	2090	2389	2731	3122	3569	73
	65	2432	2780	3178	3633	4152	83
	70	2761	3156	3608	4124	4715	92

able 16.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 30 square feet.

nitial age (Years)	Final age	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
45	45	787	900	1028	1175	1344	30
	50	1069	1222	1397	1597	1825	39
	55	1372	1568	1793	2049	2342	49
	60	1686	1927	2203	2518	2878	58
	65	2002	2289	2616	2990	3418	68
	70	2314	2646	3024	3457	3952	77
	75	2618	2993	3421	3911	4471	86
50	50	818	935	1069	1222	1397	30
	55	1077	1231	1407	1608	1839	38
	60	1353	1547	1768	2021	2310	47
	65	1639	1874	2142	2448	2799	56
	70	1928	2204	2520	2880	3293	64
	75	2216	2533	2895	3309	3783	73
	80	2497	2854	3263	3730	4264	81
55	55	845	965	1104	1261	1442	30
	60	1084	1239	1416	1619	1850	38
	65	1337	1529	1748	1998	2284	45
	70	1600	1829	2091	2390	2732	53
	75	1866	2133	2438	2787	3186	61
	80	2132	2437	2785	3184	3640	69
60	60	867	991	1133	1295	1481	30
	65	1089	1245	1423	1627	1860	37
	70	1324	1514	1730	1978	2261	44
	75	1567	1791	2047	2340	2675	51
	80	1813	2072	2369	2708	3095	58
65	65	887	1014	1159	1325	1514	30
	70	1094	1251	1430	1634	1868	36
	75	1313	1500	1715	1961	2241	43
	80	1538	1758	2010	2297	2626	50
70	70	904	1033	1181	1350	1544	30
	75	1098	1256	1435	1641	1876	36
	80	1303	1489	1702	1946	2224	42
75	75	919	1051	1201	1373	1569	30
	80	1102	1260	1440	1646	1882	35
80	80	933	1066	1219	1393	1592	30

Table 17.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 40 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
20	20	645	738	843	964	1102	40
	25	1231	1407	1609	1839	2102	64
	30	1869	2136	2442	2791	3191	87
	35	2488	2844	3250	3716	4247	106
	40	3055	3492	3991	4562	5215	123
	45	3559	4068	4650	5316	6077	136
	50	4002	4574	5229	5977	6833	147
25	25	769	879	1004	1148	1312	40
	30	1280	1463	1673	1912	2186	59
	35	1827	2089	2388	2729	3120	78
	40	2366	2704	3091	3533	4039	95
	45	2871	3282	3752	4289	4902	110
	50	3333	3810	4356	4979	5691	123
	55	3749	4286	4899	5600	6402	134
30	30	863	987	1128	1290	1474	40
	35	1316	1504	1719	1965	2247	56
	40	1794	2051	2344	2680	3063	72
	45	2269	2594	2965	3389	3874	87
	50	2722	3112	3557	4066	4648	100
	55	3145	3595	4109	4697	5370	112
	60	3533	4039	4617	5277	6033	123
35	35	938	1073	1226	1402	1602	40
	40	1343	1535	1755	2006	2293	54
	45	1767	2020	2310	2640	3018	68
	50	2191	2505	2863	3273	3741	81
	55	2601	2973	3398	3884	4440	93
	60	2988	3415	3904	4463	5102	104
	65	3349	3828	4376	5003	5719	114
40	40	999	1142	1305	1492	1705	40
	45	1365	1560	1783	2038	2330	52
	50	1746	1996	2281	2608	2981	64
	55	2128	2432	2780	3178	3633	76
	60	2500	2858	3267	3734	4269	87
	65	2856	3265	3732	4266	4877	97
	70	3193	3649	4172	4769	5451	106

Table 17.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 40 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
45	45	1048	1198	1370	1566	1790	40
	50	1382	1580	1806	2064	2359	51
	55	1728	1975	2258	2581	2950	62
	60	2075	2372	2712	3100	3543	72
	65	2416	2762	3157	3609	4125	82
	70	2745	3138	3587	4100	4687	91
	75	3058	3496	3996	4568	5222	100
50	50	1090	1246	1424	1628	1861	40
	55	1396	1596	1824	2085	2384	50
	60	1713	1958	2238	2558	2924	59
	65	2031	2322	2654	3034	3468	69
	70	2345	2681	3064	3503	4004	78
	75	2650	3029	3463	3958	4525	87
	80	2943	3364	3845	4396	5025	95
55	55	1125	1286	1470	1680	1921	40
	60	1408	1610	1840	2103	2404	49
	65	1700	1943	2221	2539	2902	58
	70	1994	2279	2605	2978	3404	66
	75	2284	2611	2985	3412	3900	75
	80	2568	2936	3356	3836	4385	83
60	60	1155	1321	1510	1726	1972	40
	65	1418	1621	1853	2119	2422	48
	70	1689	1930	2207	2523	2884	56
	75	1961	2242	2563	2930	3349	64
	80	2232	2551	2916	3334	3811	72
65	65	1181	1350	1544	1765	2017	40
	70	1427	1631	1865	2132	2437	47
	75	1679	1920	2194	2508	2867	55
	80	1933	2210	2526	2888	3301	62
70	70	1204	1377	1574	1799	2056	40
	75	1435	1640	1875	2143	2450	47
	80	1671	1910	2183	2496	2853	54
75	75	1224	1400	1600	1829	2091	40
	80	1442	1648	1884	2153	2461	46
80	80	1242	1420	1623	1856	2121	40

Table 18.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 50 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
20	20	806	922	1053	1204	1376	50
	25	1461	1670	1909	2182	2494	76
	30	2138	2444	2793	3193	3650	99
	35	2771	3168	3621	4139	4732	119
	40	3337	3814	4360	4984	5698	134
	45	3831	4379	5006	5722	6541	147
	50	4259	4868	5565	6361	7271	157
25	25	960	1097	1254	1434	1639	50
	30	1533	1752	2003	2289	2617	71
	35	2118	2421	2768	3164	3616	91
	40	2675	3058	3495	3996	4567	107
	45	3185	3640	4161	4757	5438	122
	50	3641	4163	4758	5439	6218	134
	55	4047	4626	5288	6044	6909	144
30	30	1079	1233	1409	1611	1842	50
	35	1585	1812	2072	2368	2707	68
	40	2100	2401	2744	3137	3586	84
	45	2595	2967	3392	3877	4432	99
	50	3057	3494	3994	4566	5219	113
	55	3479	3976	4545	5196	5939	124
	60	3860	4412	5043	5765	6590	134
35	35	1172	1340	1532	1751	2001	50
	40	1626	1858	2124	2428	2776	65
	45	2085	2383	2724	3114	3560	80
	50	2530	2892	3306	3779	4320	93
	55	2950	3372	3855	4406	5037	105
	60	3340	3818	4364	4988	5702	116
	65	3697	4227	4831	5523	6313	126
40	40	1248	1426	1630	1864	2130	50
	45	1658	1895	2166	2476	2830	63
	50	2072	2368	2707	3094	3537	76
	55	2475	2829	3234	3697	4226	88
	60	2860	3269	3737	4272	4883	99
	65	3221	3682	4209	4811	5500	109
	70	3557	4066	4647	5313	6073	119

able 18.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 50 square feet.

nitial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
45	45	1310	1497	1711	1956	2236	50
	50	1684	1924	2200	2515	2875	62
	55	2060	2355	2692	3077	3518	73
	60	2429	2777	3174	3629	4148	84
	65	2784	3182	3637	4158	4753	94
	70	3119	3566	4076	4659	5326	104
	75	3434	3926	4488	5130	5864	113
50	50	1361	1556	1779	2034	2325	50
	55	1705	1949	2228	2547	2911	61
	60	2050	2344	2679	3063	3501	71
	65	2390	2732	3123	3570	4081	81
	70	2718	3107	3552	4060	4641	91
	75	3031	3465	3961	4528	5176	99
	80	3328	3804	4348	4971	5682	107
55	55	1405	1606	1836	2099	2400	50
	60	1723	1969	2251	2573	2942	60
	65	2042	2334	2668	3050	3487	69
	70	2357	2694	3079	3520	4024	78
	75	2662	3043	3478	3976	4545	87
	80	2955	3378	3861	4414	5045	95
60	60	1443	1650	1886	2155	2464	50
	65	1738	1987	2271	2596	2968	59
	70	2035	2326	2659	3039	3474	68
	75	2327	2660	3041	3476	3974	76
	80	2613	2987	3414	3902	4461	84
65	65	1476	1687	1928	2204	2520	50
	70	1751	2002	2289	2616	2990	58
	75	2028	2318	2650	3029	3463	66
	80	2302	2631	3008	3438	3930	74
70	70	1504	1720	1966	2247	2569	50
	75	1763	2015	2304	2633	3010	58
	80	2022	2312	2643	3021	3453	65
75	75	1530	1748	1999	2285	2612	50
	80	1773	2027	2317	2648	3027	57
80	80	1552	1774	2028	2318	2650	50

Table 19.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 60 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
20	20	967	1105	1263	1444	1651	60
	25	1676	1916	2190	2504	2862	87
	30	2379	2720	3109	3554	4062	111
	35	3018	3450	3944	4508	5153	129
	40	3577	4089	4674	5343	6107	144
	45	4058	4639	5302	6061	6929	155
	50	4470	5110	5841	6677	7633	165
25	25	1151	1316	1505	1720	1966	60
	30	1772	2026	2316	2647	3026	82
	35	2383	2724	3114	3560	4069	102
	40	2949	3371	3853	4405	5035	118
	45	3456	3950	4516	5162	5901	132
	50	3903	4462	5100	5830	6665	144
	55	4295	4910	5613	6416	7334	153
30	30	1294	1479	1690	1932	2209	60
	35	1843	2107	2408	2753	3147	79
	40	2383	2724	3114	3559	4068	96
	45	2889	3302	3775	4315	4932	111
	50	3351	3830	4378	5005	5721	123
	55	3766	4305	4921	5626	6431	134
	60	4137	4729	5406	6180	7064	144
35	35	1406	1607	1837	2100	2400	60
	40	1898	2169	2479	2834	3240	76
	45	2380	2721	3110	3556	4064	91
	50	2837	3243	3708	4238	4845	104
	55	3260	3727	4260	4870	5567	116
	60	3647	4169	4765	5447	6227	127
	65	3997	4569	5223	5970	6825	136
40	40	1496	1710	1955	2235	2555	60
	45	1941	2218	2536	2899	3314	74
	50	2377	2718	3106	3551	4059	87
	55	2794	3193	3650	4173	4770	100
	60	3183	3639	4159	4755	5435	111
	65	3543	4050	4630	5292	6050	120
	70	3873	4428	5061	5786	6614	129

Table 19.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 60 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
45	45	1571	1795	2052	2346	2682	60
	50	1976	2259	2582	2951	3374	73
	55	2374	2714	3102	3546	4054	85
	60	2756	3151	3601	4117	4706	96
	65	3117	3563	4072	4655	5321	106
	70	3453	3947	4512	5158	5896	115
	75	3765	4303	4919	5623	6428	123
50	50	1633	1867	2134	2439	2788	60
	55	2005	2292	2620	2995	3423	71
	60	2371	2710	3098	3542	4048	82
	65	2724	3113	3559	4068	4651	92
	70	3059	3497	3997	4569	5223	102
	75	3374	3857	4409	5040	5761	111
	80	3668	4193	4794	5479	6264	118
55	55	1686	1927	2202	2518	2878	60
	60	2030	2320	2652	3031	3465	70
	65	2368	2707	3094	3537	4043	80
	70	2696	3081	3522	4026	4603	90
	75	3008	3439	3931	4494	5137	99
	80	3305	3778	4318	4936	5642	107
60	60	1731	1978	2262	2585	2955	60
	65	2050	2344	2679	3063	3501	70
	70	2365	2704	3091	3533	4039	79
	75	2671	3053	3490	3989	4560	87
	80	2964	3388	3873	4428	5061	96
65	65	1770	2023	2313	2644	3022	60
	70	2069	2365	2703	3090	3532	69
	75	2363	2701	3088	3529	4034	77
	80	2649	3028	3462	3957	4523	85
70	70	1804	2062	2358	2695	3081	60
	75	2084	2383	2724	3113	3559	68
	80	2361	2698	3084	3526	4030	76
75	75	1834	2097	2397	2740	3132	60
	80	2098	2398	2742	3134	3583	68
80	80	1861	2128	2432	2780	3178	60

Table 20.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 70 square feet.

Initial age	Final age	Site index					Projected basal area
		50	60	70	80	90	
(Years)							(sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
20	20	1127	1289	1473	1684	1925	70
	25	1880	2149	2457	2809	3211	98
	30	2599	2971	3396	3883	4438	121
	35	3237	3700	4230	4835	5527	139
	40	3786	4327	4947	5655	6464	152
	45	4253	4861	5557	6352	7261	163
	50	4650	5315	6076	6945	7939	171
25	25	1343	1535	1754	2006	2293	70
	30	2001	2287	2615	2989	3417	93
	35	2628	3005	3434	3926	4488	112
	40	3196	3653	4176	4773	5456	128
	45	3696	4224	4829	5520	6310	142
	50	4131	4722	5398	6171	7054	152
	55	4510	5155	5893	6736	7700	161
30	30	1508	1724	1971	2253	2576	70
	35	2091	2390	2732	3123	3570	89
	40	2646	3025	3458	3953	4519	106
	45	3156	3608	4124	4714	5389	121
	50	3614	4131	4722	5398	6170	133
	55	4020	4595	5253	6004	6864	143
	60	4379	5006	5722	6541	7477	152
35	35	1639	1874	2142	2449	2799	70
	40	2160	2469	2823	3227	3688	87
	45	2658	3039	3474	3971	4539	102
	50	3120	3567	4077	4661	5328	115
	55	3541	4048	4627	5289	6046	126
	60	3920	4481	5123	5856	6694	136
	65	4260	4870	5567	6364	7275	145
40	40	1745	1995	2280	2606	2979	70
	45	2215	2532	2895	3309	3783	85
	50	2667	3048	3484	3983	4553	98
	55	3089	3531	4036	4614	5274	110
	60	3478	3975	4544	5195	5938	121
	65	3832	4381	5008	5725	6544	130
	70	4154	4749	5429	6205	7094	139

Table 20.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 70 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
45	45	1832	2094	2393	2736	3127	70
	50	2260	2584	2954	3376	3859	83
	55	2673	3055	3492	3992	4563	95
	60	3061	3499	4000	4572	5227	106
	65	3422	3912	4472	5112	5843	116
	70	3755	4292	4906	5609	6411	125
	75	4060	4641	5305	6064	6932	133
50	50	1904	2177	2488	2844	3251	70
	55	2298	2627	3002	3432	3923	82
	60	2677	3060	3498	3999	4571	93
	65	3037	3471	3968	4536	5185	103
	70	3373	3856	4408	5039	5760	112
	75	3686	4214	4817	5506	6294	121
	80	3975	4544	5195	5938	6788	128
55	55	1966	2247	2568	2936	3356	70
	60	2329	2663	3044	3479	3977	81
	65	2681	3064	3503	4004	4577	91
	70	3015	3447	3940	4504	5148	100
	75	3330	3807	4352	4974	5686	109
	80	3625	4144	4737	5415	6190	117
60	60	2018	2307	2637	3015	3446	70
	65	2356	2693	3079	3519	4023	80
	70	2683	3067	3506	4008	4582	89
	75	2996	3425	3915	4475	5115	98
	80	3292	3763	4302	4917	5621	106
65	65	2064	2359	2697	3083	3524	70
	70	2379	2720	3109	3554	4063	79
	75	2685	3070	3509	4011	4585	88
	80	2979	3405	3893	4450	5086	96
70	70	2104	2405	2749	3143	3592	70
	75	2400	2743	3136	3585	4098	79
	80	2687	3072	3511	4014	4588	87
75	75	2139	2445	2795	3195	3653	70
	80	2418	2764	3159	3611	4128	78
80	80	2171	2481	2836	3242	3706	70

Table 21.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 80 square feet.

Initial age	Final age	Site index					Projected basal are
(Years)		50	60	70	80	90	(sq. ft.
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
20	20	1288	1472	1683	1924	2199	80
	25	2075	2372	2711	3099	3542	108
	30	2802	3203	3662	4186	4785	130
	35	3434	3926	4488	5130	5864	147
	40	3971	4539	5189	5931	6780	160
	45	4423	5056	5780	6607	7553	169
	50	4806	5493	6279	7178	8205	177
25	25	1534	1753	2004	2291	2619	80
	30	2221	2538	2902	3317	3792	103
	35	2857	3266	3733	4267	4878	122
	40	3421	3910	4470	5109	5841	138
	45	3911	4470	5110	5841	6677	150
	50	4333	4953	5662	6472	7399	160
	55	4697	5370	6138	7016	8021	168
30	30	1723	1970	2252	2574	2942	80
	35	2330	2663	3045	3480	3978	100
	40	2894	3309	3782	4323	4942	116
	45	3402	3889	4446	5082	5809	130
	50	3852	4403	5033	5754	6577	142
	55	4247	4855	5549	6343	7251	152
	60	4593	5250	6002	6860	7842	160
35	35	1873	2141	2447	2797	3198	80
	40	2415	2760	3155	3607	4123	97
	45	2922	3340	3818	4364	4988	112
	50	3383	3867	4421	5054	5777	125
	55	3798	4341	4963	5673	6485	136
	60	4167	4764	5446	6225	7116	145
	65	4496	5139	5875	6716	7677	153
40	40	1993	2279	2605	2977	3403	80
	45	2483	2838	3244	3708	4239	95
	50	2942	3363	3844	4395	5024	108
	55	3365	3846	4397	5026	5745	120
	60	3749	4286	4899	5600	6401	130
	65	4096	4682	5352	6118	6993	139
	70	4408	5038	5759	6584	7526	147

Table 21.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 80 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
45	45	2092	2392	2734	3125	3573	80
	50	2538	2901	3316	3791	4333	93
	55	2958	3382	3865	4419	5051	105
	60	3348	3827	4375	5001	5716	116
	65	3705	4236	4842	5535	6327	126
	70	4031	4608	5268	6022	6884	134
	75	4328	4947	5655	6464	7389	142
50	50	2175	2487	2842	3249	3714	80
	55	2584	2954	3376	3860	4412	92
	60	2971	3396	3882	4438	5073	103
	65	3332	3809	4354	4978	5690	113
	70	3667	4191	4791	5477	6260	122
	75	3974	4543	5193	5936	6785	130
	80	4255	4864	5560	6356	7266	138
55	55	2245	2567	2934	3354	3834	80
	60	2623	2998	3427	3918	4478	91
	65	2982	3408	3896	4454	5091	101
	70	3318	3793	4336	4956	5666	111
	75	3632	4152	4746	5425	6201	119
	80	3922	4483	5125	5858	6697	127
60	60	2306	2636	3013	3444	3937	80
	65	2656	3036	3471	3968	4535	90
	70	2990	3418	3907	4467	5106	100
	75	3305	3779	4319	4937	5644	108
	80	3601	4116	4705	5378	6148	116
65	65	2358	2695	3081	3522	4026	80
	70	2685	3069	3508	4011	4585	89
	75	2998	3427	3917	4478	5118	98
	80	3294	3765	4304	4920	5624	106
70	70	2404	2748	3141	3590	4104	80
	75	2710	3098	3541	4048	4628	89
	80	3004	3434	3925	4487	5129	97
75	75	2444	2794	3193	3650	4173	80
	80	2732	3123	3570	4081	4665	88
80	80	2480	2835	3240	3704	4234	80

Table 22.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 90 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
20	20	1449	1656	1893	2164	2473	90
	25	2261	2584	2954	3377	3860	118
	30	2991	3419	3908	4467	5106	139
	35	3614	4131	4722	5398	6171	155
	40	4137	4729	5406	6180	7064	166
	45	4575	5230	5978	6834	7812	175
	50	4943	5650	6459	7383	8440	182
25	25	1725	1972	2254	2577	2945	90
	30	2432	2780	3178	3633	4153	113
	35	3071	3511	4013	4588	5244	131
	40	3628	4147	4741	5419	6195	146
	45	4106	4694	5365	6133	7011	157
	50	4515	5161	5899	6744	7709	166
	55	4865	5561	6357	7266	8306	174
30	30	1938	2215	2532	2895	3309	90
	35	2562	2928	3347	3826	4374	110
	40	3129	3577	4089	4674	5343	126
	45	3631	4151	4745	5424	6200	139
	50	4070	4653	5319	6080	6950	150
	55	4453	5090	5818	6651	7603	159
	60	4785	5470	6253	7148	8171	166
35	35	2106	2408	2752	3146	3596	90
	40	2663	3044	3479	3977	4546	107
	45	3172	3626	4145	4738	5416	121
	50	3629	4149	4742	5421	6197	134
	55	4035	4612	5272	6027	6889	144
	60	4393	5022	5741	6562	7501	153
	65	4709	5383	6154	7034	8041	160
40	40	2242	2562	2929	3348	3828	90
	45	2743	3136	3585	4098	4684	105
	50	3206	3664	4189	4788	5474	118
	55	3625	4144	4737	5414	6189	129
	60	4001	4574	5229	5977	6832	139
	65	4338	4959	5668	6479	7407	147
	70	4638	5302	6061	6928	7920	155

Table 22.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 90 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
45	45	2353	2690	3075	3515	4018	90
	50	2809	3211	3671	4196	4797	103
	55	3232	3695	4224	4828	5519	115
	60	3619	4137	4729	5406	6180	126
	65	3970	4538	5188	5930	6779	135
	70	4287	4901	5602	6404	7320	143
	75	4573	5228	5976	6831	7808	150
50	50	2446	2796	3197	3654	4177	90
	55	2864	3274	3743	4279	4891	102
	60	3254	3720	4252	4861	5557	113
	65	3613	4130	4722	5397	6170	123
	70	3942	4506	5151	5888	6731	131
	75	4241	4848	5542	6335	7242	139
	80	4513	5159	5898	6742	7706	146
55	55	2525	2887	3300	3772	4312	90
	60	2911	3328	3804	4348	4971	101
	65	3272	3741	4276	4888	5588	111
	70	3607	4124	4714	5388	6159	120
	75	3916	4476	5117	5849	6686	128
	80	4199	4800	5487	6273	7170	136
60	60	2593	2964	3388	3873	4427	90
	65	2951	3373	3856	4408	5039	100
	70	3288	3758	4296	4911	5614	110
	75	3602	4117	4706	5380	6150	118
	80	3893	4450	5086	5814	6646	126
65	65	2652	3031	3465	3961	4528	90
	70	2986	3413	3901	4460	5098	99
	75	3301	3773	4313	4930	5636	108
	80	3596	4111	4699	5371	6140	116
70	70	2703	3090	3532	4038	4615	90
	75	3016	3448	3941	4505	5150	99
	80	3312	3786	4328	4947	5655	107
75	75	2748	3142	3591	4105	4693	90
	80	3043	3478	3976	4545	5195	98
80	80	2789	3188	3644	4165	4762	90

Table 23.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 100 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
20	20	1609	1839	2102	2403	2747	100
	25	2439	2788	3187	3643	4165	127
	30	3167	3620	4138	4731	5408	147
	35	3779	4320	4938	5645	6453	162
	40	4288	4902	5603	6405	7322	172
	45	4711	5386	6156	7037	8045	181
	50	5066	5791	6620	7567	8650	187
25	25	1916	2190	2504	2862	3272	100
	30	2637	3014	3446	3939	4503	123
	35	3274	3743	4278	4890	5590	140
	40	3821	4367	4992	5707	6524	154
	45	4285	4898	5599	6401	7317	164
	50	4679	5349	6115	6990	7990	172
	55	5016	5733	6554	7492	8564	179
30	30	2153	2461	2813	3215	3676	100
	35	2787	3186	3642	4163	4758	119
	40	3352	3832	4380	5007	5724	135
	45	3846	4396	5025	5744	6566	147
	50	4272	4884	5583	6381	7295	157
	55	4641	5305	6064	6932	7924	166
	60	4960	5670	6481	7409	8469	172
35	35	2339	2674	3057	3494	3994	100
	40	2904	3320	3795	4338	4959	117
	45	3412	3900	4458	5096	5826	131
	50	3861	4414	5045	5767	6593	142
	55	4255	4864	5561	6356	7266	152
	60	4601	5260	6012	6873	7856	160
	65	4904	5606	6408	7325	8374	167
40	40	2490	2846	3254	3719	4252	100
	45	2998	3427	3918	4478	5119	115
	50	3459	3954	4520	5166	5906	127
	55	3871	4425	5058	5782	6610	138
	60	4237	4844	5537	6329	7235	147
	65	4562	5215	5962	6815	7790	155
	70	4850	5545	6338	7245	8282	162

able 23.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 100 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
45	45	2614	2988	3415	3904	4463	100
	50	3075	3515	4019	4594	5251	113
	55	3497	3997	4569	5223	5971	125
	60	3877	4432	5067	5792	6621	135
	65	4219	4823	5513	6302	7204	143
	70	4526	5173	5914	6760	7727	151
	75	4800	5487	6272	7170	8196	157
50	50	2717	3106	3551	4059	4640	100
	55	3140	3589	4103	4690	5361	112
	60	3528	4033	4610	5270	6024	123
	65	3882	4437	5072	5798	6628	132
	70	4202	4803	5491	6276	7175	140
	75	4491	5134	5869	6709	7669	147
	80	4753	5433	6211	7099	8115	154
55	55	2805	3206	3665	4190	4789	100
	60	3194	3652	4174	4772	5454	111
	65	3554	4063	4644	5309	6069	121
	70	3884	4440	5076	5802	6632	129
	75	4186	4785	5469	6252	7147	137
	80	4460	5098	5828	6662	7615	144
60	60	2880	3292	3763	4302	4918	100
	65	3241	3705	4235	4842	5534	110
	70	3577	4089	4674	5342	6107	119
	75	3886	4442	5078	5805	6635	127
	80	4170	4767	5449	6229	7120	135
65	65	2945	3367	3849	4399	5029	100
	70	3282	3752	4289	4902	5604	109
	75	3596	4111	4699	5371	6140	118
	80	3887	4443	5079	5806	6637	126
70	70	3002	3432	3923	4485	5126	100
	75	3318	3792	4335	4956	5665	109
	80	3613	4130	4721	5396	6168	117
75	75	3053	3490	3989	4560	5212	100
	80	3349	3828	4376	5002	5718	108
80	80	3098	3541	4048	4627	5289	100

Table 24.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 110 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
20	20	1769	2023	2312	2643	3021	110
	25	2611	2985	3412	3900	4458	136
	30	3333	3810	4355	4979	5691	155
	35	3932	4495	5138	5874	6714	168
	40	4426	5060	5784	6612	7558	178
	45	4835	5527	6318	7223	8256	185
	50	5177	5918	6765	7733	8839	191
25	25	2107	2409	2753	3147	3598	110
	30	2835	3241	3705	4235	4841	132
	35	3466	3962	4529	5177	5918	148
	40	4001	4573	5227	5976	6831	161
	45	4451	5087	5815	6648	7599	171
	50	4830	5522	6312	7215	8248	178
	55	5153	5890	6733	7697	8798	184
30	30	2367	2706	3093	3536	4042	110
	35	3006	3436	3928	4490	5133	129
	40	3565	4076	4659	5325	6088	143
	45	4047	4626	5288	6045	6910	155
	50	4460	5098	5828	6662	7615	164
	55	4815	5504	6291	7192	8221	172
	60	5120	5853	6690	7648	8742	178
35	35	2573	2941	3362	3843	4393	110
	40	3140	3589	4103	4690	5361	126
	45	3642	4163	4759	5440	6218	139
	50	4080	4664	5332	6095	6967	150
	55	4462	5101	5830	6665	7619	159
	60	4794	5480	6264	7161	8186	167
	65	5084	5811	6643	7593	8680	173
40	40	2738	3130	3578	4090	4675	110
	45	3248	3713	4244	4851	5545	124
	50	3703	4233	4838	5531	6322	136
	55	4105	4693	5364	6132	7009	147
	60	4459	5098	5827	6661	7614	155
	65	4772	5454	6235	7127	8147	162
	70	5047	5769	6595	7539	8617	168

Table 24.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 110 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
45	45	2874	3286	3756	4293	4908	110
	50	3336	3814	4360	4984	5697	123
	55	3752	4289	4903	5605	6407	134
	60	4124	4714	5389	6160	7041	143
	65	4455	5092	5821	6654	7606	151
	70	4749	5429	6205	7093	8109	158
	75	5011	5728	6548	7485	8556	164
50	50	2988	3416	3905	4463	5102	110
	55	3411	3899	4456	5094	5823	122
	60	3794	4336	4957	5666	6477	132
	65	4139	4731	5408	6182	7067	141
	70	4449	5085	5813	6645	7596	148
	75	4727	5403	6177	7060	8071	155
	80	4977	5689	6503	7434	8497	161
55	55	3085	3526	4031	4607	5267	110
	60	3473	3970	4539	5188	5931	121
	65	3828	4376	5002	5718	6537	130
	70	4150	4744	5423	6199	7087	138
	75	4442	5078	5804	6635	7585	146
	80	4706	5379	6149	7029	8035	152
60	60	3167	3620	4139	4731	5408	110
	65	3527	4032	4609	5269	6023	120
	70	3858	4410	5041	5763	6587	129
	75	4160	4755	5436	6214	7103	136
	80	4435	5070	5795	6625	7573	143
65	65	3239	3702	4232	4838	5530	110
	70	3574	4086	4671	5339	6103	119
	75	3884	4439	5075	5801	6631	127
	80	4168	4764	5446	6226	7117	135
70	70	3302	3774	4314	4932	5638	110
	75	3615	4133	4724	5400	6173	118
	80	3906	4465	5104	5835	6669	126
75	75	3357	3838	4387	5014	5732	110
	80	3652	4174	4772	5455	6235	118
80	80	3406	3894	4451	5088	5816	110

Table 25.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 120 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
20	20	1930	2206	2522	2882	3295	120
	25	2777	3175	3629	4148	4742	145
	30	3490	3990	4560	5213	5959	162
	35	4075	4658	5325	6087	6958	174
	40	4554	5206	5951	6802	7776	183
	45	4949	5657	6467	7392	8450	190
	50	5278	6033	6897	7884	9012	195
25	25	2298	2627	3003	3433	3924	120
	30	3028	3461	3957	4523	5170	141
	35	3649	4172	4769	5451	6231	156
	40	4169	4766	5448	6228	7119	168
	45	4604	5263	6016	6877	7862	176
	50	4970	5681	6494	7423	8485	183
	55	5279	6034	6898	7885	9013	189
30	30	2582	2951	3374	3856	4408	120
	35	3220	3681	4207	4809	5498	138
	40	3769	4309	4925	5630	6436	152
	45	4238	4844	5537	6330	7236	162
	50	4636	5299	6058	6925	7916	171
	55	4976	5688	6502	7432	8496	178
	60	5268	6021	6883	7868	8994	183
35	35	2806	3207	3666	4191	4791	120
	40	3371	3853	4405	5035	5755	135
	45	3863	4416	5048	5770	6596	148
	50	4289	4903	5604	6406	7323	158
	55	4656	5323	6084	6955	7950	166
	60	4974	5686	6500	7430	8493	173
	65	5250	6002	6860	7842	8964	179
40	40	2986	3414	3902	4461	5099	120
	45	3493	3992	4564	5217	5963	134
	50	3938	4502	5146	5883	6724	145
	55	4328	4948	5656	6465	7391	155
	60	4669	5338	6102	6975	7973	162
	65	4968	5679	6492	7421	8482	169
	70	5230	5978	6834	7812	8930	174

able 25.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 120 square feet.

nitial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
45	45	3135	3583	4096	4682	5353	120
	50	3593	4107	4695	5367	6135	132
	55	4000	4572	5227	5975	6830	143
	60	4360	4984	5697	6513	7445	152
	65	4678	5348	6113	6988	7988	159
	70	4959	5669	6480	7408	8468	165
	75	5208	5954	6806	7780	8893	171
50	50	3259	3725	4258	4868	5564	120
	55	3677	4203	4805	5492	6278	131
	60	4051	4631	5294	6052	6918	141
	65	4386	5013	5731	6551	7488	149
	70	4684	5354	6120	6996	7997	156
	75	4949	5658	6467	7393	8451	162
	80	5187	5929	6778	7748	8856	168
55	55	3364	3845	4396	5025	5744	120
	60	3748	4285	4898	5599	6400	130
	65	4095	4681	5351	6117	6992	139
	70	4407	5038	5758	6583	7525	147
	75	4687	5358	6125	7001	8003	154
	80	4939	5646	6454	7377	8433	160
60	60	3454	3949	4514	5160	5898	120
	65	3810	4355	4978	5690	6505	129
	70	4132	4724	5400	6172	7056	138
	75	4425	5058	5782	6609	7555	145
	80	4689	5360	6127	7004	8007	152
65	65	3532	4038	4616	5276	6032	120
	70	3863	4416	5048	5770	6596	129
	75	4165	4761	5442	6221	7111	137
	80	4440	5075	5802	6632	7581	143
70	70	3601	4116	4705	5379	6148	120
	75	3910	4469	5109	5840	6676	128
	80	4193	4793	5479	6263	7160	135
75	75	3661	4185	4784	5469	6252	120
	80	3951	4517	5163	5902	6746	128
80	80	3715	4247	4854	5549	6343	120

Table 26.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 130 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.
		50	60	70	80	90	
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
20	20	2090	2389	2731	3122	3569	130
	25	2938	3358	3839	4388	5016	154
	30	3639	4160	4755	5436	6213	169
	35	4209	4811	5499	6286	7186	180
	40	4672	5341	6105	6979	7978	188
	45	5054	5777	6604	7549	8629	194
	50	5371	6139	7018	8022	9170	198
25	25	2489	2845	3252	3718	4250	130
	30	3216	3676	4202	4803	5491	150
	35	3824	4372	4997	5712	6530	164
	40	4329	4948	5657	6466	7391	174
	45	4748	5428	6204	7092	8107	182
	50	5099	5828	6663	7616	8706	188
	55	5395	6167	7049	8058	9211	193
30	30	2796	3196	3654	4177	4775	130
	35	3429	3919	4480	5121	5854	147
	40	3966	4533	5182	5923	6771	159
	45	4418	5051	5774	6600	7544	169
	50	4801	5488	6274	7172	8198	177
	55	5126	5860	6699	7657	8753	183
	60	5404	6178	7062	8073	9228	188
35	35	3039	3474	3971	4539	5189	130
	40	3597	4112	4700	5373	6141	145
	45	4077	4660	5327	6089	6961	156
	50	4488	5130	5864	6703	7662	165
	55	4840	5532	6324	7229	8264	173
	60	5143	5879	6720	7682	8782	179
	65	5406	6179	7063	8074	9230	184
40	40	3234	3697	4226	4831	5523	130
	45	3733	4267	4878	5576	6374	143
	50	4166	4763	5444	6223	7114	154
	55	4542	5192	5936	6785	7756	162
	60	4869	5565	6362	7272	8313	169
	65	5153	5890	6733	7697	8798	175
	70	5401	6174	7058	8068	9223	180

Table 26.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 130 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
45	45	3395	3881	4437	5071	5797	130
	50	3845	4395	5024	5743	6565	142
	55	4240	4847	5541	6334	7240	151
	60	4587	5243	5994	6851	7832	159
	65	4891	5591	6391	7305	8351	166
	70	5158	5896	6740	7705	8807	172
	75	5394	6166	7049	8057	9210	177
50	50	3530	4035	4612	5272	6027	130
	55	3939	4503	5147	5884	6726	141
	60	4302	4918	5622	6426	7346	150
	65	4624	5285	6042	6906	7895	157
	70	4908	5611	6414	7331	8381	164
	75	5161	5899	6743	7708	8812	169
	80	5385	6156	7037	8044	9195	174
55	55	3643	4165	4761	5442	6221	130
	60	4019	4594	5252	6004	6863	140
	65	4355	4978	5691	6505	7436	148
	70	4655	5321	6082	6953	7948	155
	75	4922	5626	6432	7352	8404	161
	80	5161	5900	6744	7709	8812	167
60	60	3741	4277	4889	5588	6388	130
	65	4088	4673	5342	6107	6980	139
	70	4400	5030	5750	6573	7513	147
	75	4681	5351	6117	6992	7992	154
	80	4933	5639	6446	7369	8423	159
65	65	3826	4373	4999	5715	6533	130
	70	4148	4742	5420	6196	7083	138
	75	4440	5075	5802	6632	7581	146
	80	4704	5377	6146	7026	8031	152
70	70	3900	4458	5096	5826	6659	130
	75	4201	4802	5489	6275	7173	138
	80	4474	5115	5847	6683	7640	145
75	75	3966	4533	5182	5923	6771	130
	80	4247	4855	5550	6344	7252	137
80	80	4024	4599	5258	6010	6870	130

Table 27.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 140 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
20	20	2250	2572	2940	3361	3842	140
	25	3094	3537	4043	4621	5283	162
	30	3781	4322	4940	5647	6456	176
	35	4334	4955	5664	6474	7401	186
	40	4783	5467	6250	7144	8167	192
	45	5151	5888	6730	7694	8795	197
	50	5456	6237	7130	8150	9316	201
25	25	2680	3063	3502	4003	4576	140
	30	3399	3885	4441	5076	5803	158
	35	3992	4563	5216	5963	6816	171
	40	4480	5121	5854	6692	7649	180
	45	4883	5582	6381	7294	8338	187
	50	5219	5966	6820	7796	8912	192
	55	5503	6290	7190	8219	9396	197
30	30	3011	3442	3934	4497	5141	140
	35	3633	4153	4747	5426	6203	155
	40	4154	4749	5429	6205	7093	167
	45	4591	5248	5999	6857	7838	176
	50	4957	5667	6478	7405	8464	183
	55	5268	6021	6883	7868	8994	188
	60	5532	6324	7229	8264	9446	192
35	35	3272	3740	4275	4887	5587	140
	40	3819	4365	4990	5704	6520	154
	45	4283	4896	5597	6398	7313	164
	50	4678	5347	6112	6987	7987	172
	55	5014	5732	6552	7489	8561	179
	60	5302	6061	6928	7920	9053	184
	65	5551	6345	7254	8292	9478	189
40	40	3482	3981	4551	5202	5946	140
	45	3969	4537	5186	5929	6777	152
	50	4388	5016	5733	6554	7492	162
	55	4748	5427	6204	7092	8107	170
	60	5059	5782	6610	7556	8637	176
	65	5328	6090	6962	7958	9097	181
	70	5563	6359	7269	8309	9498	186

able 27.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 140 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
45	45	3656	4179	4777	5460	6242	140
	50	4093	4679	5349	6114	6989	151
	55	4474	5114	5846	6683	7639	160
	60	4805	5493	6279	7178	8205	167
	65	5094	5823	6657	7609	8698	173
	70	5347	6112	6987	7987	9130	178
	75	5570	6367	7278	8319	9510	183
50	50	3800	4344	4966	5676	6489	140
	55	4198	4799	5485	6270	7168	150
	60	4547	5198	5941	6792	7764	158
	65	4854	5548	6342	7250	8287	165
	70	5123	5857	6695	7653	8748	171
	75	5362	6129	7006	8009	9155	176
	80	5573	6371	7282	8324	9516	180
55	55	3923	4484	5126	5860	6698	140
	60	4287	4900	5602	6403	7320	149
	65	4609	5269	6023	6884	7870	157
	70	4894	5595	6396	7311	8357	163
	75	5148	5884	6726	7689	8789	169
	80	5373	6142	7021	8026	9174	174
60	60	4028	4605	5263	6017	6878	140
	65	4363	4988	5702	6518	7450	148
	70	4663	5330	6093	6964	7961	155
	75	4930	5635	6441	7363	8417	162
	80	5168	5908	6753	7720	8824	167
65	65	4119	4709	5383	6153	7034	140
	70	4430	5064	5789	6617	7564	148
	75	4709	5383	6154	7034	8041	154
	80	4960	5670	6481	7409	8469	160
70	70	4199	4800	5487	6272	7170	140
	75	4489	5131	5865	6705	7664	147
	80	4750	5430	6207	7096	8111	154
75	75	4270	4881	5579	6377	7290	140
	80	4541	5190	5933	6782	7753	147
80	80	4332	4952	5661	6471	7397	140

Table 28.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 150 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
20	20	2411	2755	3150	3601	4116	150
	25	3246	3710	4241	4848	5542	170
	30	3916	4477	5117	5850	6687	182
	35	4453	5090	5819	6651	7603	191
	40	4886	5586	6385	7299	8343	197
	45	5241	5991	6849	7829	8949	201
	50	5536	6328	7233	8269	9452	204
25	25	2871	3281	3751	4288	4901	150
	30	3577	4089	4674	5343	6108	166
	35	4153	4747	5427	6204	7091	178
	40	4623	5285	6041	6906	7894	186
	45	5010	5727	6547	7484	8555	192
	50	5332	6095	6968	7965	9105	197
	55	5603	6405	7322	8370	9567	200
30	30	3225	3687	4214	4817	5507	150
	35	3833	4382	5009	5725	6545	164
	40	4337	4957	5667	6478	7405	174
	45	4755	5436	6214	7103	8119	182
	50	5105	5836	6671	7626	8717	188
	55	5400	6173	7057	8067	9221	193
	60	5652	6461	7385	8442	9651	197
35	35	3505	4006	4580	5235	5984	150
	40	4036	4614	5274	6029	6892	162
	45	4483	5125	5858	6697	7655	172
	50	4860	5556	6351	7259	8298	179
	55	5180	5921	6768	7737	8844	185
	60	5453	6233	7125	8145	9310	190
	65	5688	6502	7432	8496	9712	194
40	40	3730	4264	4875	5572	6370	150
	45	4201	4803	5490	6276	7174	161
	50	4603	5261	6014	6875	7859	170
	55	4945	5653	6462	7387	8444	177
	60	5240	5990	6847	7827	8947	182
	65	5494	6280	7179	8206	9381	187
	70	5715	6533	7468	8536	9758	191

Table 28.--Current and projected total cubic foot volumes, o.b., (VOT) and projected basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area = 150 square feet.

Initial age (Years)	Final age	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VOT (cubic feet,o.b.,/acre)					BT2
45	45	3916	4476	5117	5849	6686	150
	50	4338	4959	5669	6480	7407	160
	55	4702	5375	6144	7023	8028	168
	60	5016	5734	6555	7493	8565	174
	65	5289	6046	6911	7900	9031	180
	70	5527	6318	7222	8256	9437	184
	75	5736	6556	7495	8567	9793	188
50	50	4071	4653	5319	6081	6951	150
	55	4453	5090	5819	6652	7603	159
	60	4786	5471	6253	7148	8171	166
	65	5076	5802	6633	7582	8667	173
	70	5330	6093	6965	7962	9101	178
	75	5554	6349	7257	8296	9483	182
	80	5752	6575	7515	8591	9820	186
55	55	4202	4804	5491	6277	7175	150
	60	4551	5202	5947	6798	7771	158
	65	4857	5553	6347	7255	8294	165
	70	5127	5861	6699	7658	8754	171
	75	5365	6133	7011	8014	9161	176
	80	5576	6374	7286	8329	9521	180
60	60	4315	4932	5638	6445	7368	150
	65	4636	5299	6057	6924	7915	158
	70	4919	5623	6428	7348	8400	164
	75	5171	5911	6757	7724	8829	170
	80	5395	6167	7050	8058	9212	174
65	65	4413	5044	5766	6591	7534	150
	70	4709	5383	6153	7034	8041	157
	75	4974	5685	6499	7429	8492	163
	80	5210	5955	6807	7781	8895	168
70	70	4498	5142	5878	6719	7680	150
	75	4774	5457	6238	7131	8151	157
	80	5021	5740	6561	7500	8573	162
75	75	4574	5228	5976	6832	7809	150
	80	4831	5523	6313	7216	8249	156
80	80	4641	5305	6064	6932	7924	150

Table 29.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 20 square feet

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
20	20	81	162	235	302	370	20
	25	307	474	611	743	884	37
	30	640	890	1102	1317	1554	56
	35	1035	1361	1650	1954	2297	74
	40	1450	1842	2207	2601	3049	91
	45	1857	2306	2742	3222	3772	106
	50	2240	2739	3241	3801	4444	119
25	25	189	272	342	412	488	20
	30	417	554	676	803	946	33
	35	709	908	1091	1289	1512	48
	40	1042	1302	1552	1827	2139	63
	45	1392	1711	2028	2381	2785	78
	50	1742	2115	2497	2926	3420	91
	55	2078	2501	2945	3447	4027	103
30	30	275	347	416	491	576	20
	35	485	601	715	842	986	31
	40	741	907	1075	1263	1477	43
	45	1027	1246	1472	1726	2018	56
	50	1329	1601	1886	2208	2580	68
	55	1634	1956	2299	2690	3141	80
	60	1932	2302	2702	3159	3688	91
35	35	332	399	470	551	644	20
	40	524	629	742	869	1015	29
	45	752	900	1059	1240	1448	40
	50	1004	1198	1407	1646	1923	50
	55	1269	1509	1771	2071	2418	61
	60	1538	1825	2139	2500	2918	72
	65	1806	2136	2502	2923	3411	81
40	40	370	437	512	599	699	20
	45	548	648	760	888	1037	28
	50	753	891	1044	1220	1425	37
	55	978	1156	1354	1582	1846	46
	60	1214	1433	1678	1960	2288	56
	65	1456	1716	2009	2346	2737	65
	70	1697	1999	2338	2729	3184	74

Table 29.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 20 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
45	45	399	468	547	638	744	20
	50	563	662	774	904	1055	27
	55	750	882	1031	1204	1405	35
	60	953	1120	1310	1529	1784	43
	65	1166	1370	1602	1870	2181	52
	70	1384	1626	1901	2218	2588	60
	75	1604	1883	2201	2568	2996	68
50	50	421	492	575	671	782	20
	55	574	672	785	916	1069	26
	60	745	873	1020	1190	1388	33
	65	930	1090	1273	1485	1733	41
	70	1124	1317	1538	1795	2094	48
	75	1323	1550	1811	2112	2464	56
	80	1524	1786	2085	2433	2837	63
55	55	440	513	599	698	815	20
	60	582	681	794	926	1080	26
	65	740	865	1010	1178	1374	32
	70	909	1064	1242	1449	1689	39
	75	1087	1272	1485	1732	2020	45
	80	1270	1486	1734	2023	2359	52
60	60	455	531	619	722	842	20
	65	589	687	802	935	1090	25
	70	735	858	1002	1168	1362	31
	75	891	1041	1215	1417	1653	37
	80	1055	1233	1439	1678	1957	43
65	65	469	547	637	743	866	20
	70	594	693	808	942	1099	25
	75	730	852	994	1159	1352	30
	80	875	1022	1192	1390	1621	36
70	70	480	560	653	761	888	20
	75	598	698	814	949	1106	25
	80	726	847	987	1151	1343	29
75	75	490	572	667	777	906	20
	80	602	702	818	954	1113	24
80	80	500	583	679	792	923	20

Table 30.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) an projected total basal area (BT2) for natural even-aged stands of lon- leaf pine in the East Gulf,initial basal area (BT1) = 30 square fee

Initial age	Final age	Site index					Projected basal are
(Years)		50	60	70	80	90	(sq. ft.
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
20	20	120	240	349	448	549	30
	25	404	640	832	1016	1212	51
	30	804	1140	1418	1699	2007	73
	35	1256	1671	2033	2411	2835	92
	40	1710	2189	2627	3099	3634	109
	45	2140	2670	3178	3737	4374	123
	50	2532	3105	3677	4313	5044	135
25	25	259	391	501	607	722	30
	30	552	758	934	1114	1314	47
	35	911	1188	1437	1700	1997	64
	40	1299	1641	1963	2313	2711	81
	45	1688	2090	2482	2916	3412	96
	50	2062	2516	2975	3488	4078	109
	55	2411	2912	3432	4018	4695	121
30	30	382	502	611	725	853	30
	35	655	833	1000	1180	1384	44
	40	971	1209	1440	1693	1983	58
	45	1309	1604	1900	2230	2608	73
	50	1649	1999	2359	2764	3230	86
	55	1979	2380	2802	3279	3830	98
	60	2294	2741	3220	3766	4397	109
35	35	471	583	693	815	955	30
	40	722	883	1046	1228	1436	42
	45	1004	1217	1437	1684	1969	54
	50	1302	1567	1845	2160	2524	67
	55	1604	1919	2255	2638	3081	78
	60	1900	2263	2656	3105	3625	89
	65	2185	2593	3040	3552	4146	100
40	40	535	643	757	887	1037	30
	45	765	917	1079	1263	1476	40
	50	1020	1218	1431	1674	1955	51
	55	1287	1532	1798	2102	2455	62
	60	1559	1849	2168	2534	2958	73
	65	1828	2163	2533	2959	3453	83
	70	2089	2466	2886	3371	3933	92

able 30.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 30 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
45	45	582	690	809	946	1105	30
	50	795	942	1105	1292	1508	39
	55	1027	1216	1425	1665	1943	49
	60	1270	1501	1758	2054	2396	58
	65	1517	1790	2095	2447	2855	68
	70	1762	2077	2429	2836	3309	77
	75	2003	2356	2755	3216	3752	86
50	50	619	728	852	995	1161	30
	55	817	962	1126	1314	1534	38
	60	1030	1213	1419	1657	1933	47
	65	1253	1474	1723	2012	2347	56
	70	1479	1739	2033	2373	2768	64
	75	1705	2002	2340	2732	3186	73
	80	1927	2262	2643	3084	3597	81
55	55	648	760	888	1037	1209	30
	60	833	978	1142	1333	1555	38
	65	1031	1209	1413	1649	1924	45
	70	1236	1450	1694	1977	2306	53
	75	1444	1694	1979	2309	2693	61
	80	1653	1938	2264	2642	3081	69
60	60	673	787	919	1072	1251	30
	65	846	990	1157	1349	1574	37
	70	1030	1206	1408	1643	1916	44
	75	1220	1428	1668	1946	2270	51
	80	1414	1655	1932	2254	2629	58
65	65	694	811	946	1104	1287	30
	70	856	1001	1169	1363	1590	36
	75	1028	1202	1403	1637	1909	43
	80	1205	1410	1645	1919	2238	50
70	70	712	831	970	1131	1319	30
	75	865	1010	1179	1375	1603	36
	80	1026	1199	1399	1631	1902	42
75	75	727	849	990	1155	1347	30
	80	872	1018	1188	1385	1615	35
80	80	741	865	1009	1176	1372	30

Table 31.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) an projected total basal area (BT2) for natural even-aged stands of lon- leaf pine in the East Gulf,initial basal area (BT1) = 40 square fee

Initial age (Years)	Final age	Site index					Projected basal are
		50	60	70	80	90	(sq. ft.
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
20	20	159	317	462	594	727	40
	25	492	790	1032	1263	1508	64
	30	942	1350	1686	2021	2389	87
	35	1433	1919	2340	2777	3266	106
	40	1911	2455	2951	3483	4085	123
	45	2351	2941	3504	4121	4825	136
	50	2744	3372	3995	4687	5482	147
25	25	328	509	657	801	954	40
	30	676	945	1171	1400	1653	59
	35	1084	1430	1735	2057	2417	78
	40	1509	1921	2302	2715	3182	95
	45	1922	2390	2843	3341	3911	110
	50	2309	2825	3343	3921	4584	123
	55	2661	3220	3797	4447	5196	134
30	30	484	655	803	956	1127	40
	35	810	1048	1264	1495	1755	56
	40	1172	1474	1761	2073	2429	72
	45	1544	1905	2261	2655	3107	87
	50	1908	2322	2744	3217	3760	100
	55	2252	2715	3199	3745	4375	112
	60	2571	3079	3619	4233	4944	123
35	35	603	762	913	1077	1262	40
	40	903	1119	1330	1564	1831	54
	45	1226	1499	1774	2081	2434	68
	50	1556	1883	2221	2602	3041	81
	55	1880	2258	2657	3110	3633	93
	60	2191	2616	3073	3593	4196	104
	65	2484	2952	3463	4047	4724	114
40	40	692	844	999	1173	1372	40
	45	966	1169	1380	1617	1890	52
	50	1258	1512	1781	2085	2435	64
	55	1555	1859	2185	2556	2985	76
	60	1849	2200	2582	3019	3524	87
	65	2132	2529	2964	3463	4042	97
	70	2402	2840	3326	3885	4534	106

Table 31.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 40 square feet.

Initial age (Years)	Final age	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
45	45	758	908	1069	1251	1462	40
	50	1011	1207	1419	1659	1938	51
	55	1278	1520	1784	2086	2435	62
	60	1548	1836	2153	2516	2937	72
	65	1816	2149	2517	2940	3431	82
	70	2077	2452	2870	3351	3910	91
	75	2327	2742	3207	3745	4369	100
50	50	810	960	1126	1316	1537	40
	55	1045	1237	1450	1694	1977	50
	60	1290	1524	1785	2086	2434	59
	65	1538	1815	2125	2481	2895	69
	70	1785	2103	2461	2873	3352	78
	75	2026	2384	2788	3254	3796	87
	80	2259	2655	3103	3622	4225	95
55	55	852	1004	1175	1372	1601	40
	60	1070	1261	1475	1722	2010	49
	65	1297	1527	1786	2085	2432	58
	70	1527	1796	2100	2451	2859	66
	75	1756	2063	2411	2814	3283	75
	80	1980	2325	2716	3170	3697	83
60	60	886	1040	1216	1419	1656	40
	65	1090	1280	1497	1747	2038	48
	70	1302	1528	1786	2084	2431	56
	75	1515	1778	2078	2424	2828	64
	80	1729	2027	2368	2763	3223	72
65	65	915	1072	1252	1461	1704	40
	70	1107	1297	1515	1767	2062	47
	75	1304	1528	1785	2083	2429	55
	80	1504	1762	2058	2401	2800	62
70	70	939	1099	1283	1497	1746	40
	75	1120	1311	1531	1786	2082	47
	80	1306	1528	1784	2081	2427	54
75	75	961	1123	1311	1529	1783	40
	80	1132	1323	1544	1801	2101	46
80	80	980	1145	1336	1558	1816	40

Table 32.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 50 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
20	20	198	395	574	738	904	50
	25	573	928	1217	1492	1782	76
	30	1063	1534	1920	2304	2724	99
	35	1581	2128	2598	3086	3630	119
	40	2074	2674	3216	3797	4454	134
	45	2519	3158	3765	4428	5185	147
	50	2911	3582	4245	4981	5826	157
25	25	396	625	813	993	1184	50
	30	791	1119	1392	1667	1969	71
	35	1238	1646	2002	2375	2792	91
	40	1690	2161	2594	3060	3588	107
	45	2118	2642	3145	3697	4328	122
	50	2510	3077	3644	4274	4998	134
	55	2862	3468	4091	4791	5599	144
30	30	583	805	993	1186	1399	50
	35	955	1250	1513	1791	2104	68
	40	1353	1714	2051	2417	2833	84
	45	1750	2169	2577	3028	3543	99
	50	2128	2598	3072	3603	4212	113
	55	2478	2994	3529	4133	4829	124
	60	2798	3355	3946	4616	5390	134
35	35	732	940	1131	1336	1568	50
	40	1072	1342	1600	1884	2206	65
	45	1428	1756	2082	2445	2860	80
	50	1781	2163	2555	2995	3500	93
	55	2119	2552	3005	3518	4109	105
	60	2437	2915	3426	4007	4679	116
	65	2731	3251	3814	4458	5204	126
40	40	845	1043	1239	1456	1704	50
	45	1156	1409	1667	1955	2286	63
	50	1476	1784	2103	2464	2879	76
	55	1794	2153	2532	2963	3461	88
	60	2101	2507	2944	3443	4020	99
	65	2392	2842	3333	3896	4547	109
	70	2665	3155	3697	4318	5039	119

Table 32.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 50 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
45	45	930	1124	1326	1554	1816	50
	50	1216	1460	1719	2012	2351	62
	55	1509	1802	2118	2477	2893	73
	60	1799	2140	2511	2935	3426	84
	65	2080	2466	2890	3377	3942	94
	70	2349	2777	3252	3798	4432	104
	75	2602	3070	3592	4194	4894	113
50	50	997	1190	1398	1636	1910	50
	55	1262	1501	1761	2059	2404	61
	60	1531	1815	2128	2487	2903	71
	65	1797	2126	2491	2910	3395	81
	70	2057	2429	2843	3320	3873	91
	75	2307	2718	3180	3712	4331	99
	80	2544	2993	3500	4085	4765	107
55	55	1051	1245	1459	1705	1990	50
	60	1297	1533	1796	2098	2448	60
	65	1546	1825	2136	2494	2911	69
	70	1793	2113	2472	2887	3368	78
	75	2035	2395	2800	3269	3813	87
	80	2268	2666	3116	3636	4242	95
60	60	1095	1291	1511	1764	2059	50
	65	1325	1560	1825	2131	2486	59
	70	1557	1832	2142	2500	2917	68
	75	1788	2101	2456	2866	3344	76
	80	2013	2364	2762	3224	3760	84
65	65	1133	1331	1556	1816	2118	50
	70	1348	1583	1850	2159	2519	58
	75	1565	1837	2147	2505	2922	66
	80	1781	2089	2441	2848	3322	74
70	70	1164	1365	1595	1861	2171	50
	75	1367	1603	1872	2184	2548	58
	80	1571	1841	2151	2509	2926	65
75	75	1192	1395	1629	1901	2217	50
	80	1384	1620	1891	2206	2573	57
80	80	1216	1422	1660	1936	2258	50

Table 33.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) ar
projected total basal area (BT2) for natural even-aged stands of lor-
leaf pine in the East Gulf,initial basal area (BT1) = 60 square fee

Initial age (Years)	Final age	Site index					Projected basal are (sq. ft.
		50	60	70	80	90	
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
20	20	236	471	686	882	1081	60
	25	649	1057	1390	1705	2038	87
	30	1172	1698	2129	2557	3024	111
	35	1710	2310	2822	3353	3945	129
	40	2213	2859	3441	4064	4767	144
	45	2659	3339	3982	4685	5485	155
	50	3048	3754	4451	5223	6109	165
25	25	464	741	968	1184	1413	60
	30	899	1284	1601	1920	2269	82
	35	1378	1842	2244	2664	3133	102
	40	1849	2374	2852	3366	3947	118
	45	2287	2859	3405	4004	4688	132
	50	2680	3292	3899	4575	5350	144
	55	3029	3675	4336	5079	5936	153
30	30	682	954	1183	1414	1670	60
	35	1093	1442	1750	2074	2437	79
	40	1519	1934	2319	2734	3205	96
	45	1933	2404	2860	3361	3934	111
	50	2320	2839	3360	3941	4608	123
	55	2673	3234	3814	4467	5219	134
	60	2991	3590	4222	4940	5770	144
35	35	859	1115	1347	1594	1872	60
	40	1234	1555	1859	2190	2566	76
	45	1615	1995	2369	2783	3256	91
	50	1983	2417	2857	3350	3916	104
	55	2330	2812	3313	3879	4532	116
	60	2650	3175	3733	4367	5099	127
	65	2943	3507	4116	4811	5617	136
40	40	995	1240	1477	1737	2035	60
	45	1336	1639	1943	2280	2667	74
	50	1680	2037	2405	2818	3294	87
	55	2012	2420	2850	3335	3896	100
	60	2328	2782	3269	3823	4464	111
	65	2621	3119	3659	4276	4991	120
	70	2893	3429	4018	4694	5478	129

Table 33.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 60 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
45	45	1100	1338	1582	1855	2169	60
	50	1413	1704	2009	2353	2749	73
	55	1725	2067	2432	2845	3323	85
	60	2029	2419	2840	3321	3877	96
	65	2318	2753	3228	3772	4402	106
	70	2590	3066	3591	4195	4895	115
	75	2843	3357	3930	4589	5354	123
50	50	1182	1418	1669	1953	2281	60
	55	1470	1755	2062	2412	2817	71
	60	1758	2090	2452	2866	3346	82
	65	2037	2414	2830	3306	3859	92
	70	2305	2724	3190	3726	4348	102
	75	2558	3017	3530	4122	4809	111
	80	2796	3292	3850	4494	5243	118
55	55	1248	1484	1741	2036	2377	60
	60	1516	1797	2107	2462	2874	70
	65	1782	2107	2468	2883	3365	80
	70	2041	2409	2819	3292	3842	90
	75	2290	2698	3156	3685	4299	99
	80	2527	2973	3476	4057	4733	107
60	60	1303	1540	1804	2107	2459	60
	65	1552	1832	2145	2505	2922	70
	70	1800	2121	2481	2897	3380	79
	75	2041	2403	2809	3280	3826	87
	80	2275	2674	3125	3648	4255	96
65	65	1348	1588	1858	2169	2531	60
	70	1582	1861	2177	2541	2965	69
	75	1814	2132	2492	2909	3393	77
	80	2040	2396	2800	3268	3812	85
70	70	1387	1629	1905	2223	2593	60
	75	1607	1887	2205	2573	3001	68
	80	1825	2141	2501	2919	3405	76
75	75	1421	1666	1946	2271	2649	60
	80	1628	1909	2229	2601	3034	68
80	80	1450	1698	1983	2313	2698	60

Table 34.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) a
projected total basal area (BT2) for natural even-aged stands of lo
leaf pine in the East Gulf,initial basal area (BT1) = 70 square fe

Initial age	Final age	Site index					Projecte basal ar
(Years)		50	60	70	80	90	(sq. ft)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
20	20	274	548	797	1026	1256	70
	25	720	1179	1554	1907	2280	98
	30	1270	1848	2320	2787	3297	121
	35	1825	2470	3021	3591	4225	139
	40	2333	3020	3637	4295	5039	152
	45	2780	3494	4168	4904	5743	163
	50	3165	3901	4625	5428	6349	171
25	25	531	857	1122	1374	1641	70
	30	1002	1440	1801	2161	2554	93
	35	1507	2023	2468	2931	3447	112
	40	1992	2565	3084	3640	4270	128
	45	2435	3050	3635	4275	5006	142
	50	2829	3478	4121	4836	5655	152
	55	3173	3852	4547	5327	6225	161
30	30	780	1102	1371	1642	1939	70
	35	1224	1626	1977	2345	2757	89
	40	1673	2139	2567	3029	3551	106
	45	2100	2619	3117	3665	4290	121
	50	2492	3055	3616	4242	4961	133
	55	2844	3445	4064	4761	5563	143
	60	3158	3793	4463	5222	6099	152
35	35	984	1290	1563	1851	2174	70
	40	1389	1761	2108	2485	2912	87
	45	1789	2219	2638	3099	3627	102
	50	2169	2650	3134	3676	4298	115
	55	2520	3046	3591	4205	4914	126
	60	2840	3407	4006	4687	5473	136
	65	3129	3732	4381	5121	5979	145
40	40	1143	1436	1714	2018	2364	70
	45	1511	1862	2209	2594	3035	85
	50	1871	2276	2689	3153	3685	98
	55	2214	2668	3143	3680	4299	110
	60	2533	3032	3564	4168	4868	121
	65	2827	3366	3950	4617	5390	130
	70	3095	3671	4303	5027	5867	139

Table 34.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 70 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
45	45	1267	1551	1836	2155	2520	70
	50	1602	1940	2290	2683	3135	83
	55	1930	2319	2729	3194	3731	95
	60	2242	2678	3146	3679	4296	106
	65	2535	3015	3536	4133	4825	116
	70	2807	3327	3898	4554	5314	125
	75	3058	3614	4231	4941	5765	133
50	50	1364	1644	1938	2269	2651	70
	55	1673	2003	2355	2756	3218	82
	60	1973	2351	2761	3228	3768	93
	65	2261	2684	3147	3677	4292	103
	70	2532	2997	3510	4100	4785	112
	75	2786	3289	3850	4495	5245	121
	80	3022	3560	4164	4862	5672	128
55	55	1443	1722	2023	2366	2762	70
	60	1728	2054	2410	2817	3288	81
	65	2006	2377	2786	3255	3799	91
	70	2273	2686	3146	3674	4287	100
	75	2526	2979	3486	4070	4748	109
	80	2764	3254	3805	4442	5182	117
60	60	1508	1788	2095	2449	2858	70
	65	1773	2097	2456	2869	3348	80
	70	2032	2398	2807	3278	3824	89
	75	2281	2687	3143	3670	4281	98
	80	2518	2962	3463	4042	4715	106
65	65	1562	1844	2158	2521	2941	70
	70	1810	2133	2496	2914	3400	79
	75	2052	2415	2824	3297	3846	88
	80	2286	2687	3141	3665	4276	96
70	70	1608	1892	2213	2584	3014	70
	75	1841	2165	2530	2954	3445	79
	80	2069	2430	2839	3314	3865	87
75	75	1648	1935	2262	2639	3079	70
	80	1868	2192	2561	2988	3485	78
80	80	1683	1973	2304	2689	3136	70

Table 35.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of loblolly pine in the East Gulf,initial basal area (BT1) = 80 square feet

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
20	20	312	624	908	1168	1431	80
	25	788	1295	1709	2099	2509	108
	30	1360	1985	2495	2999	3548	130
	35	1927	2615	3200	3804	4476	147
	40	2440	3162	3810	4500	5280	160
	45	2885	3629	4331	5096	5968	169
	50	3266	4027	4776	5606	6557	177
25	25	599	972	1276	1564	1869	80
	30	1101	1590	1992	2391	2828	103
	35	1626	2191	2676	3179	3739	122
	40	2123	2738	3295	3890	4563	138
	45	2568	3221	3841	4518	5291	150
	50	2960	3643	4317	5067	5926	160
	55	3300	4008	4732	5544	6479	168
30	30	877	1250	1559	1868	2208	80
	35	1350	1803	2196	2606	3064	100
	40	1818	2332	2801	3305	3876	116
	45	2253	2816	3354	3944	4617	130
	50	2647	3250	3849	4516	5281	142
	55	2997	3634	4288	5023	5870	152
	60	3305	3974	4676	5472	6391	160
35	35	1108	1464	1777	2107	2476	80
	40	1538	1959	2349	2770	3247	97
	45	1954	2431	2891	3399	3978	112
	50	2341	2866	3392	3978	4651	125
	55	2694	3261	3845	4503	5262	136
	60	3011	3615	4253	4976	5811	145
	65	3295	3933	4617	5398	6302	153
40	40	1290	1630	1950	2297	2692	80
	45	1679	2078	2468	2899	3393	95
	50	2052	2503	2960	3470	4057	108
	55	2401	2899	3417	4001	4674	120
	60	2721	3262	3835	4486	5239	130
	65	3013	3591	4215	4928	5752	139
	70	3277	3889	4559	5327	6217	147

Table 35.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 80 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
45	45	1433	1762	2090	2454	2870	80
	50	1786	2170	2563	3004	3511	93
	55	2125	2559	3013	3527	4121	105
	60	2442	2922	3434	4016	4690	116
	65	2737	3258	3822	4468	5215	126
	70	3007	3565	4178	4882	5697	134
	75	3253	3846	4503	5259	6137	142
50	50	1545	1870	2206	2584	3020	80
	55	1869	2244	2641	3091	3610	92
	60	2179	2602	3056	3574	4172	103
	65	2472	2938	3446	4027	4701	113
	70	2744	3250	3808	4449	5192	122
	75	2996	3539	4143	4838	5645	130
	80	3228	3805	4451	5197	6063	138
55	55	1637	1959	2303	2694	3147	80
	60	1935	2305	2706	3164	3693	91
	65	2222	2636	3091	3612	4216	101
	70	2492	2949	3454	4035	4708	111
	75	2746	3242	3794	4430	5169	119
	80	2983	3514	4110	4798	5597	127
60	60	1711	2034	2386	2789	3256	80
	65	1989	2356	2761	3226	3765	90
	70	2255	2665	3120	3644	4252	100
	75	2508	2957	3460	4040	4714	108
	80	2746	3232	3780	4413	5148	116
65	65	1774	2098	2458	2871	3351	80
	70	2033	2400	2809	3280	3827	89
	75	2282	2689	3145	3672	4284	98
	80	2519	2963	3465	4044	4718	106
70	70	1828	2154	2521	2943	3434	80
	75	2070	2437	2850	3327	3881	89
	80	2304	2709	3166	3696	4311	97
75	75	1874	2203	2576	3007	3507	80
	80	2102	2470	2886	3368	3929	88
80	80	1914	2247	2625	3063	3573	80

Table 36.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 90 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
20	20	350	700	1018	1311	1606	90
	25	853	1406	1857	2281	2729	118
	30	1444	2113	2658	3196	3782	139
	35	2021	2746	3362	3998	4705	155
	40	2535	3290	3965	4684	5496	166
	45	2978	3750	4476	5267	6168	175
	50	3354	4139	4909	5763	6741	182
25	25	666	1086	1429	1753	2096	90
	30	1195	1734	2175	2613	3090	113
	35	1738	2349	2871	3411	4014	131
	40	2242	2898	3489	4121	4834	146
	45	2689	3377	4028	4739	5549	157
	50	3077	3791	4494	5274	6168	166
	55	3412	4147	4896	5737	6705	174
30	30	974	1397	1746	2094	2476	90
	35	1472	1974	2407	2858	3362	110
	40	1954	2513	3021	3566	4183	126
	45	2395	2999	3573	4203	4921	139
	50	2789	3428	4062	4766	5574	150
	55	3135	3805	4491	5261	6148	159
	60	3438	4136	4867	5696	6653	166
35	35	1232	1637	1991	2362	2776	90
	40	1683	2152	2583	3047	3572	107
	45	2110	2632	3133	3683	4311	121
	50	2502	3067	3632	4261	4982	134
	55	2854	3458	4079	4778	5583	144
	60	3168	3805	4477	5239	6119	153
	65	3446	4114	4831	5649	6595	160
40	40	1437	1824	2185	2576	3019	90
	45	1842	2287	2720	3196	3740	105
	50	2225	2720	3218	3774	4412	118
	55	2577	3116	3674	4303	5027	129
	60	2896	3475	4087	4781	5584	139
	65	3184	3798	4458	5212	6085	147
	70	3442	4087	4792	5600	6535	155

Table 36.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 90 square feet.

Initial age (Years)	Final age	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
45	45	1597	1973	2343	2752	3220	90
	50	1965	2394	2830	3317	3878	103
	55	2311	2788	3285	3847	4494	115
	60	2631	3152	3705	4334	5062	126
	65	2924	3484	4089	4780	5580	135
	70	3190	3786	4437	5185	6051	143
	75	3431	4059	4753	5551	6478	150
50	50	1725	2094	2473	2898	3387	90
	55	2061	2480	2920	3418	3993	102
	60	2377	2842	3340	3906	4561	113
	65	2671	3179	3729	4359	5088	123
	70	2942	3488	4088	4775	5573	131
	75	3190	3771	4415	5157	6017	139
	80	3417	4030	4715	5505	6422	146
55	55	1829	2195	2582	3022	3530	90
	60	2137	2551	2996	3503	4090	101
	65	2429	2886	3385	3956	4618	111
	70	2701	3199	3748	4379	5110	120
	75	2954	3489	4084	4769	5565	128
	80	3186	3756	4394	5130	5984	136
60	60	1914	2280	2676	3128	3652	90
	65	2200	2610	3060	3576	4174	100
	70	2470	2923	3423	3998	4666	110
	75	2724	3215	3763	4394	5127	118
	80	2961	3488	4080	4763	5556	126
65	65	1985	2352	2757	3221	3759	90
	70	2252	2661	3116	3639	4246	99
	75	2504	2953	3456	4035	4707	108
	80	2742	3228	3775	4407	5141	116
70	70	2046	2415	2827	3301	3852	90
	75	2295	2705	3164	3694	4309	99
	80	2533	2980	3484	4066	4744	107
75	75	2099	2470	2889	3373	3935	90
	80	2333	2743	3206	3742	4365	98
80	80	2144	2519	2944	3436	4008	90

Table 37.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) ad projected total basal area (BT2) for natural even-aged stands of log- leaf pine in the East Gulf,initial basal area (BT1) = 100 square fe

Initial age (Years)	Final age	Site index 50	60	70	80	90	Projecte basal ar (sq. ft)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
20	20	388	776	1129	1453	1780	100
	25	915	1512	1999	2457	2939	127
	30	1523	2233	2810	3379	3999	147
	35	2106	2867	3512	4176	4916	162
	40	2622	3406	4106	4851	5692	172
	45	3062	3858	4606	5421	6348	181
	50	3434	4239	5028	5903	6904	187
25	25	733	1201	1582	1942	2322	100
	30	1287	1873	2352	2827	3344	123
	35	1844	2497	3054	3631	4272	140
	40	2353	3046	3669	4334	5084	154
	45	2800	3520	4199	4941	5786	164
	50	3184	3925	4654	5462	6389	172
	55	3513	4272	5045	5911	6908	179
30	30	1070	1544	1933	2320	2743	100
	35	1590	2140	2612	3103	3650	119
	40	2083	2685	3231	3814	4474	135
	45	2528	3170	3779	4445	5204	147
	50	2920	3593	4258	4997	5844	157
	55	3262	3962	4676	5479	6403	166
	60	3558	4283	5041	5899	6890	172
35	35	1355	1810	2204	2616	3076	100
	40	1823	2339	2810	3316	3888	117
	45	2259	2823	3363	3955	4630	131
	50	2653	3257	3858	4526	5293	142
	55	3003	3641	4297	5033	5882	152
	60	3311	3981	4684	5481	6402	160
	65	3583	4280	5026	5877	6862	167
40	40	1582	2018	2420	2854	3346	100
	45	2002	2492	2965	3486	4080	115
	50	2391	2928	3465	4065	4753	127
	55	2743	3321	3917	4588	5361	138
	60	3060	3674	4322	5057	5906	147
	65	3342	3989	4684	5476	6393	155
	70	3594	4270	5006	5850	6828	162

Table 37.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 100 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
45	45	1761	2183	2595	3049	3568	100
	50	2140	2613	3090	3624	4237	113
	55	2490	3009	3547	4154	4853	125
	60	2811	3370	3963	4637	5415	135
	65	3100	3697	4339	5073	5922	143
	70	3361	3991	4678	5466	6380	151
	75	3596	4255	4984	5821	6792	157
50	50	1904	2318	2739	3211	3754	100
	55	2248	2711	3194	3739	4368	112
	60	2568	3075	3614	4228	4937	123
	65	2861	3408	4000	4675	5458	132
	70	3129	3712	4351	5083	5933	140
	75	3372	3988	4670	5454	6364	147
	80	3592	4239	4960	5791	6756	154
55	55	2020	2430	2861	3349	3912	100
	60	2335	2792	3280	3836	4479	111
	65	2629	3128	3670	4289	5007	121
	70	2901	3438	4029	4707	5493	129
	75	3150	3723	4359	5090	5940	137
	80	3378	3983	4660	5441	6348	144
60	60	2116	2524	2965	3467	4047	100
	65	2407	2860	3354	3919	4575	110
	70	2679	3173	3717	4342	5067	119
	75	2932	3463	4054	4734	5523	127
	80	3165	3731	4364	5095	5944	135
65	65	2196	2605	3054	3569	4166	100
	70	2466	2918	3417	3992	4658	109
	75	2720	3211	3757	4387	5119	118
	80	2957	3483	4074	4756	5548	126
70	70	2264	2675	3133	3659	4269	100
	75	2517	2968	3473	4055	4731	109
	80	2754	3243	3792	4427	5164	117
75	75	2322	2737	3202	3738	4361	100
	80	2560	3012	3522	4111	4795	108
80	80	2374	2791	3263	3808	4442	100

Table 38.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 110 square feet

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
20	20	426	851	1239	1595	1953	110
	25	975	1614	2136	2626	3141	136
	30	1597	2345	2952	3552	4204	155
	35	2186	2979	3650	4341	5110	168
	40	2702	3512	4235	5004	5872	178
	45	3139	3957	4724	5560	6512	185
	50	3505	4329	5136	6029	7052	191
25	25	800	1315	1735	2130	2548	110
	30	1375	2008	2524	3034	3590	132
	35	1944	2638	3229	3838	4517	148
	40	2457	3185	3837	4533	5318	161
	45	2902	3651	4357	5127	6004	171
	50	3282	4048	4800	5634	6590	178
	55	3605	4386	5179	6069	7093	184
30	30	1166	1690	2119	2545	3010	110
	35	1704	2301	2811	3340	3930	129
	40	2206	2850	3430	4051	4752	143
	45	2653	3330	3972	4672	5471	155
	50	3042	3746	4441	5212	6095	164
	55	3378	4106	4847	5679	6637	172
	60	3669	4417	5200	6085	7108	178
35	35	1477	1982	2417	2870	3376	110
	40	1960	2522	3032	3578	4197	126
	45	2402	3007	3584	4215	4935	139
	50	2795	3436	4071	4777	5587	150
	55	3141	3813	4500	5272	6161	159
	60	3444	4143	4876	5706	6665	167
	65	3709	4432	5206	6088	7108	173
40	40	1727	2210	2654	3131	3671	110
	45	2157	2692	3205	3769	4412	124
	50	2550	3128	3703	4345	5081	136
	55	2901	3516	4148	4859	5678	147
	60	3213	3861	4543	5316	6209	155
	65	3490	4167	4894	5722	6680	162
	70	3734	4438	5205	6082	7099	168

able 38.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 110 square feet

nitial age (Years)	Final age	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
45	45	1924	2393	2846	3345	3915	110
	50	2311	2827	3346	3924	4588	123
	55	2663	3223	3800	4451	5200	134
	60	2981	3578	4209	4925	5751	143
	65	3266	3897	4576	5350	6245	151
	70	3521	4182	4904	5730	6688	158
	75	3749	4438	5198	6071	7084	164
50	50	2082	2541	3005	3523	4119	110
	55	2432	2937	3462	4054	4736	122
	60	2752	3299	3879	4538	5300	132
	65	3043	3628	4258	4978	5811	141
	70	3306	3924	4601	5375	6274	148
	75	3543	4192	4909	5734	6691	155
	80	3756	4433	5188	6058	7067	161
55	55	2211	2664	3139	3675	4293	110
	60	2530	3028	3559	4163	4862	121
	65	2824	3363	3946	4613	5384	130
	70	3092	3668	4299	5022	5862	138
	75	3336	3945	4620	5396	6296	146
	80	3558	4198	4912	5734	6690	152
60	60	2316	2769	3253	3804	4442	110
	65	2610	3105	3643	4258	4970	120
	70	2882	3416	4002	4676	5457	129
	75	3131	3701	4333	5060	5904	136
	80	3360	3962	4635	5412	6313	143
65	65	2405	2858	3351	3917	4572	110
	70	2677	3171	3715	4339	5064	119
	75	2930	3461	4051	4731	5520	127
	80	3163	3729	4362	5092	5941	135
70	70	2481	2935	3437	4015	4685	110
	75	2734	3228	3777	4411	5146	118
	80	2971	3500	4094	4779	5575	126
75	75	2545	3002	3513	4102	4786	110
	80	2783	3277	3833	4474	5219	118
80	80	2602	3062	3581	4179	4875	110

Table 39.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 120 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
20	20	464	927	1349	1736	2127	120
	25	1033	1713	2267	2788	3336	145
	30	1666	2451	3087	3715	4397	162
	35	2260	3083	3779	4495	5291	174
	40	2775	3610	4354	5145	6037	183
	45	3208	4047	4832	5688	6661	190
	50	3571	4411	5234	6144	7187	195
25	25	866	1428	1887	2318	2773	120
	30	1461	2139	2690	3235	3828	141
	35	2039	2772	3394	4036	4750	156
	40	2554	3315	3995	4720	5538	168
	45	2996	3773	4504	5300	6207	176
	50	3372	4161	4935	5793	6776	183
	55	3689	4490	5303	6214	7263	189
30	30	1262	1836	2304	2769	3276	120
	35	1816	2458	3005	3572	4203	138
	40	2324	3007	3621	4277	5018	152
	45	2770	3482	4154	4887	5723	162
	50	3156	3889	4611	5412	6330	171
	55	3486	4239	5006	5865	6855	178
	60	3770	4541	5346	6257	7308	183
35	35	1599	2154	2629	3123	3674	120
	40	2094	2700	3248	3835	4498	135
	45	2539	3184	3796	4465	5228	148
	50	2931	3606	4274	5016	5866	158
	55	3272	3974	4691	5496	6423	166
	60	3568	4294	5055	5916	6910	173
	65	3826	4574	5373	6283	7336	179
40	40	1871	2403	2887	3408	3996	120
	45	2309	2888	3440	4046	4737	134
	50	2703	3320	3933	4615	5397	145
	55	3052	3702	4369	5118	5980	155
	60	3358	4038	4752	5561	6495	162
	65	3628	4334	5090	5952	6949	169
	70	3865	4595	5389	6298	7351	174

Table 39.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 120 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
45	45	2087	2602	3097	3641	4262	120
	50	2478	3038	3596	4219	4933	132
	55	2830	3429	4045	4738	5536	143
	60	3145	3778	4444	5200	6073	152
	65	3424	4088	4800	5612	6552	159
	70	3671	4363	5116	5979	6978	165
	75	3891	4608	5398	6305	7358	171
50	50	2260	2764	3270	3835	4484	120
	55	2612	3160	3725	4363	5098	131
	60	2931	3517	4137	4840	5652	141
	65	3218	3838	4506	5269	6151	149
	70	3474	4126	4838	5653	6598	156
	75	3704	4384	5135	5998	6999	162
	80	3910	4616	5402	6308	7359	168
55	55	2400	2898	3416	4000	4673	120
	60	2721	3261	3834	4485	5238	130
	65	3012	3590	4214	4927	5751	139
	70	3276	3888	4558	5326	6216	147
	75	3514	4158	4869	5687	6636	154
	80	3729	4401	5150	6013	7015	160
60	60	2516	3012	3540	4141	4836	120
	65	2810	3347	3927	4590	5359	129
	70	3079	3652	4280	5001	5837	138
	75	3324	3930	4602	5375	6272	145
	80	3546	4183	4895	5715	6667	152
65	65	2614	3109	3648	4264	4977	120
	70	2885	3420	4007	4682	5464	129
	75	3135	3705	4338	5066	5911	137
	80	3363	3966	4640	5417	6320	143
70	70	2697	3194	3742	4371	5101	120
	75	2949	3483	4078	4762	5556	128
	80	3182	3751	4388	5122	5976	135
75	75	2768	3267	3824	4466	5210	120
	80	3004	3539	4140	4833	5638	128
80	80	2830	3333	3898	4550	5308	120

Table 40.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) ad projected total basal area (BT2) for natural even-aged stands of log leaf pine in the East Gulf,initial basal area (BT1) = 130 square fe

Initial age	Final age	Site index					Projecte basal ara
(Years)		50	60	70	80	90	(sq. ft)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
20	20	501	1002	1458	1877	2300	130
	25	1089	1808	2395	2946	3525	154
	30	1732	2551	3215	3869	4581	169
	35	2329	3180	3899	4639	5461	180
	40	2843	3700	4464	5276	6191	188
	45	3273	4130	4932	5805	6799	194
	50	3630	4487	5323	6250	7311	198
25	25	933	1542	2039	2506	2998	130
	30	1544	2265	2851	3430	4059	150
	35	2130	2900	3552	4225	4973	164
	40	2646	3437	4144	4896	5745	174
	45	3085	3887	4641	5462	6397	182
	50	3455	4266	5060	5940	6948	188
	55	3767	4586	5417	6348	7419	193
30	30	1358	1981	2490	2993	3541	130
	35	1924	2611	3195	3798	4469	147
	40	2437	3158	3805	4494	5273	159
	45	2882	3626	4326	5091	5962	169
	50	3263	4024	4772	5601	6551	177
	55	3587	4364	5153	6039	7057	183
	60	3864	4656	5482	6416	7494	188
35	35	1721	2325	2841	3376	3972	130
	40	2224	2874	3460	4086	4793	145
	45	2671	3354	4000	4706	5510	156
	50	3060	3768	4467	5243	6132	165
	55	3395	4127	4872	5708	6671	173
	60	3685	4436	5223	6112	7139	179
	65	3935	4706	5528	6465	7548	184
40	40	2015	2595	3120	3684	4320	130
	45	2458	3080	3671	4318	5055	143
	50	2851	3507	4155	4876	5702	154
	55	3195	3880	4579	5365	6269	162
	60	3496	4206	4950	5793	6766	169
	65	3758	4491	5276	6169	7202	175
	70	3987	4742	5562	6500	7586	180

Table 40.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 130 square feet.

Initial age (Years)	Final age	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
45	45	2249	2810	3347	3936	4608	130
	50	2642	3244	3842	4508	5272	142
	55	2992	3629	4282	5016	5861	151
	60	3301	3969	4670	5465	6383	159
	65	3573	4269	5013	5862	6844	166
	70	3813	4534	5317	6213	7252	172
	75	4026	4769	5586	6525	7614	177
50	50	2437	2986	3535	4146	4848	130
	55	2789	3378	3985	4667	5454	141
	60	3105	3729	4387	5133	5995	150
	65	3385	4041	4745	5548	6477	157
	70	3635	4319	5065	5918	6908	164
	75	3857	4567	5350	6249	7291	169
	80	4055	4788	5604	6544	7635	174
55	55	2590	3132	3692	4324	5053	130
	60	2909	3490	4105	4802	5608	140
	65	3196	3812	4476	5233	6109	148
	70	3453	4101	4809	5619	6558	155
	75	3684	4361	5107	5966	6961	161
	80	3891	4594	5376	6277	7324	167
60	60	2716	3255	3827	4477	5228	130
	65	3008	3585	4208	4919	5742	139
	70	3271	3883	4552	5318	6207	147
	75	3509	4152	4863	5679	6627	154
	80	3724	4396	5144	6006	7007	159
65	65	2822	3361	3944	4610	5381	130
	70	3090	3666	4296	5020	5858	138
	75	3335	3943	4618	5393	6293	146
	80	3556	4196	4909	5732	6687	152
70	70	2912	3452	4045	4726	5515	130
	75	3161	3736	4374	5109	5961	138
	80	3388	3996	4675	5458	6368	145
75	75	2990	3532	4135	4828	5634	130
	80	3222	3798	4443	5187	6051	137
80	80	3057	3603	4214	4919	5739	130

Table 41.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of long leaf pine in the East Gulf,initial basal area (BT1) = 140 square feet

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
20	20	539	1077	1568	2018	2472	140
	25	1143	1901	2518	3098	3708	162
	30	1795	2647	3337	4017	4755	176
	35	2394	3272	4012	4774	5620	186
	40	2906	3785	4567	5397	6334	192
	45	3332	4206	5024	5914	6927	197
	50	3686	4556	5406	6347	7425	201
25	25	999	1655	2190	2693	3222	140
	30	1626	2389	3009	3620	4285	158
	35	2217	3022	3704	4406	5186	171
	40	2732	3553	4285	5063	5941	180
	45	3168	3994	4770	5614	6574	187
	50	3533	4364	5177	6078	7109	192
	55	3839	4675	5523	6472	7564	197
30	30	1453	2127	2675	3216	3806	140
	35	2030	2760	3379	4018	4729	155
	40	2545	3303	3981	4703	5519	167
	45	2988	3762	4491	5285	6189	176
	50	3364	4151	4923	5779	6760	183
	55	3682	4481	5292	6201	7248	188
	60	3952	4763	5609	6565	7668	192
35	35	1843	2496	3053	3628	4269	140
	40	2352	3045	3667	4332	5082	154
	45	2799	3518	4197	4939	5783	164
	50	3183	3923	4652	5460	6386	172
	55	3512	4271	5043	5909	6906	179
	60	3794	4570	5381	6297	7356	184
	65	4037	4829	5674	6635	7747	189
40	40	2158	2786	3353	3959	4644	140
	45	2605	3268	3897	4584	5368	152
	50	2995	3687	4370	5129	5998	162
	55	3333	4050	4781	5602	6547	170
	60	3626	4365	5139	6014	7024	176
	65	3880	4640	5451	6374	7442	181
	70	4102	4880	5724	6690	7808	186

able 41.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 140 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
45	45	2411	3018	3597	4230	4953	140
	50	2804	3447	4084	4792	5605	151
	55	3150	3823	4512	5286	6177	160
	60	3452	4153	4887	5719	6680	167
	65	3716	4441	5217	6100	7122	173
	70	3948	4695	5507	6436	7512	178
	75	4152	4920	5764	6733	7857	183
50	50	2613	3207	3799	4457	5212	140
	55	2964	3594	4240	4967	5804	150
	60	3274	3935	4630	5418	6328	158
	65	3547	4237	4976	5818	6792	165
	70	3789	4504	5282	6172	7204	171
	75	4002	4741	5553	6487	7570	176
	80	4192	4951	5795	6767	7896	180
55	55	2778	3365	3969	4648	5431	140
	60	3094	3716	4371	5115	5974	149
	65	3375	4029	4731	5531	6457	157
	70	3625	4307	5051	5902	6889	163
	75	3847	4556	5336	6233	7274	169
	80	4046	4778	5592	6530	7618	174
60	60	2915	3498	4114	4813	5620	140
	65	3202	3819	4484	5242	6120	148
	70	3459	4108	4817	5628	6569	155
	75	3690	4367	5115	5974	6972	162
	80	3896	4600	5383	6286	7333	167
65	65	3030	3611	4239	4955	5785	140
	70	3293	3909	4582	5354	6248	148
	75	3530	4177	4891	5713	6666	154
	80	3744	4419	5171	6038	7044	160
70	70	3127	3710	4348	5080	5929	140
	75	3370	3986	4667	5451	6361	147
	80	3591	4236	4957	5788	6752	154
75	75	3211	3796	4444	5190	6056	140
	80	3437	4054	4743	5537	6460	147
80	80	3284	3872	4530	5288	6170	140

Table 42.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of long leaf pine in the East Gulf,initial basal area (BT1) = 150 square feet

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
20	20	576	1152	1677	2159	2645	150
	25	1196	1990	2638	3246	3885	170
	30	1855	2738	3453	4157	4922	182
	35	2455	3358	4119	4902	5771	191
	40	2965	3864	4663	5511	6468	197
	45	3388	4278	5110	6016	7046	201
	50	3737	4620	5483	6438	7530	204
25	25	1066	1768	2342	2880	3446	150
	30	1705	2509	3162	3805	4504	166
	35	2300	3140	3849	4579	5390	178
	40	2815	3663	4418	5221	6127	186
	45	3246	4095	4891	5757	6742	192
	50	3606	4455	5286	6206	7260	197
	55	3906	4758	5621	6588	7699	200
30	30	1549	2272	2859	3440	4071	150
	35	2134	2906	3560	4234	4984	164
	40	2650	3443	4151	4905	5755	174
	45	3089	3893	4648	5470	6406	182
	50	3459	4271	5066	5948	6957	188
	55	3770	4591	5422	6354	7427	193
	60	4034	4863	5727	6704	7830	197
35	35	1964	2666	3264	3880	4566	150
	40	2477	3212	3871	4573	5365	162
	45	2922	3677	4388	5164	6047	172
	50	3301	4072	4829	5668	6630	179
	55	3623	4408	5206	6100	7129	185
	60	3897	4696	5530	6472	7560	190
	65	4133	4945	5811	6795	7934	194
40	40	2301	2977	3585	4234	4967	150
	45	2748	3453	4119	4846	5675	161
	50	3134	3862	4579	5374	6286	170
	55	3466	4214	4976	5830	6813	177
	60	3751	4518	5319	6225	7271	182
	65	3997	4781	5617	6568	7669	187
	70	4210	5010	5877	6869	8018	191

Table 42.--Current and projected merchantable cubic foot volumes,i.b.,(VIM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf,initial basal area (BT1) = 150 square feet.

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq ft.)
A1	A2	VIM (cubic feet,i.b.,/acre)					BT2
45	45	2572	3226	3846	4524	5297	150
	50	2963	3647	4322	5072	5932	160
	55	3303	4012	4736	5549	6485	168
	60	3597	4330	5097	5965	6967	174
	65	3853	4607	5412	6328	7389	180
	70	4076	4849	5688	6648	7759	184
	75	4272	5063	5932	6929	8086	188
50	50	2789	3429	4062	4767	5574	150
	55	3135	3806	4491	5262	6149	159
	60	3438	4136	4868	5697	6653	166
	65	3704	4426	5199	6079	7097	173
	70	3936	4681	5490	6416	7489	178
	75	4141	4906	5748	6714	7835	182
	80	4322	5106	5977	6979	8143	186
55	55	2967	3597	4244	4972	5810	150
	60	3277	3939	4634	5423	6334	158
	65	3550	4240	4980	5823	6798	165
	70	3791	4507	5285	6176	7209	171
	75	4005	4744	5557	6491	7574	176
	80	4194	4954	5799	6771	7900	180
60	60	3113	3740	4399	5148	6012	150
	65	3394	4051	4757	5562	6494	158
	70	3643	4329	5076	5931	6923	164
	75	3864	4576	5360	6261	7306	170
	80	4062	4797	5614	6556	7649	174
65	65	3237	3861	4534	5300	6188	150
	70	3492	4148	4864	5683	6633	157
	75	3721	4405	5160	6027	7032	163
	80	3926	4636	5425	6335	7391	168
70	70	3341	3967	4651	5434	6342	150
	75	3577	4233	4957	5790	6756	157
	80	3789	4472	5233	6111	7129	162
75	75	3432	4059	4754	5552	6478	150
	80	3650	4307	5040	5884	6865	156
80	80	3510	4141	4845	5657	6600	150

Table 43.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) an projected total basal area (BT2) for natural even-aged stands of lon leaf pine in the East Gulf, initial basal area (BT1) = 20 square fe

Initial age (Years)	Final age	Site index					Projecte basal are (sq. ft
		50	60	70	80	90	
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
20	20	120	233	332	419	503	20
	25	437	662	836	998	1165	37
	30	892	1218	1477	1731	2003	56
	35	1421	1832	2178	2530	2915	74
	40	1968	2451	2879	3328	3825	91
	45	2497	3041	3545	4085	4688	106
	50	2990	3585	4159	4782	5482	119
25	25	266	375	463	546	635	20
	30	575	750	897	1045	1206	33
	35	965	1211	1428	1654	1903	48
	40	1404	1720	2011	2320	2664	63
	45	1861	2242	2606	2999	3440	78
	50	2312	2752	3187	3662	4197	91
	55	2743	3238	3738	4290	4914	103
30	30	376	465	546	632	727	20
	35	654	795	928	1071	1230	31
	40	990	1189	1382	1591	1826	43
	45	1364	1622	1879	2160	2476	56
	50	1754	2071	2393	2747	3147	68
	55	2146	2519	2903	3330	3814	80
	60	2528	2952	3398	3895	4459	91
35	35	443	523	605	695	797	20
	40	696	819	946	1086	1245	29
	45	991	1164	1343	1541	1765	40
	50	1316	1540	1775	2036	2331	50
	55	1657	1933	2224	2550	2919	61
	60	2003	2329	2677	3068	3511	72
	65	2344	2719	3122	3576	4092	81
40	40	487	564	649	743	851	20
	45	718	832	957	1097	1255	28
	50	982	1139	1309	1500	1717	37
	55	1270	1472	1691	1937	2217	46
	60	1572	1820	2090	2393	2739	56
	65	1880	2174	2495	2856	3268	65
	70	2188	2526	2897	3316	3794	74

Table 43.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 20 square feet

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
45	45	518	596	683	782	895	20
	50	730	841	964	1104	1263	27
	55	969	1117	1281	1466	1677	35
	60	1228	1415	1623	1857	2125	43
	65	1499	1727	1980	2267	2593	52
	70	1777	2046	2345	2684	3070	60
	75	2055	2366	2711	3102	3548	68
50	50	542	622	712	814	931	20
	55	738	847	970	1109	1269	26
	60	955	1097	1257	1438	1645	33
	65	1190	1367	1566	1792	2049	41
	70	1436	1650	1890	2162	2473	48
	75	1688	1940	2221	2541	2906	56
	80	1943	2232	2555	2923	3343	63
55	55	561	643	735	841	962	20
	60	743	851	974	1114	1273	26
	65	943	1081	1237	1415	1617	32
	70	1157	1327	1519	1737	1986	39
	75	1382	1585	1814	2075	2372	45
	80	1613	1850	2117	2422	2769	52
60	60	577	661	756	864	988	20
	65	746	854	977	1117	1277	25
	70	931	1066	1219	1394	1594	31
	75	1128	1292	1479	1691	1933	37
	80	1335	1529	1750	2001	2288	43
65	65	591	676	773	884	1010	20
	70	749	857	980	1120	1280	25
	75	920	1053	1205	1377	1575	30
	80	1103	1263	1444	1651	1888	36
70	70	603	689	788	901	1030	20
	75	751	859	982	1122	1283	25
	80	911	1042	1192	1362	1557	29
75	75	613	701	801	916	1047	20
	80	752	860	984	1125	1286	24
80	80	622	711	813	930	1063	20

Table 44.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of loblolly leaf pine in the East Gulf, initial basal area (BT1) = 30 square fe

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
20	20	178	349	497	627	753	30
	25	580	899	1147	1374	1606	51
	30	1127	1567	1912	2245	2600	73
	35	1732	2260	2695	3135	3614	92
	40	2330	2923	3441	3980	4576	109
	45	2887	3531	4122	4752	5454	123
	50	3388	4075	4731	5442	6239	135
25	25	367	544	683	812	947	30
	30	768	1033	1248	1460	1688	47
	35	1247	1595	1891	2195	2528	64
	40	1758	2179	2556	2952	3392	81
	45	2266	2750	3203	3689	4233	96
	50	2748	3287	3810	4381	5022	109
	55	3194	3781	4369	5017	5747	121
30	30	526	679	809	941	1085	30
	35	890	1110	1306	1512	1739	44
	40	1307	1595	1862	2147	2466	58
	45	1746	2099	2438	2805	3217	73
	50	2186	2598	3007	3455	3959	86
	55	2611	3078	3552	4077	4669	98
	60	3011	3528	4064	4660	5335	109
35	35	635	770	899	1036	1190	30
	40	964	1157	1343	1546	1774	42
	45	1332	1583	1833	2106	2414	54
	50	1717	2026	2340	2687	3078	67
	55	2105	2470	2847	3265	3739	78
	60	2485	2901	3339	3827	4381	89
	65	2848	3313	3808	4363	4993	100
40	40	710	836	966	1110	1272	30
	45	1010	1186	1369	1571	1799	40
	50	1338	1567	1805	2071	2372	51
	55	1682	1963	2259	2590	2965	62
	60	2030	2361	2714	3110	3560	73
	65	2372	2752	3161	3621	4143	83
	70	2704	3130	3593	4114	4706	92

ble 44.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 30 square feet

itial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
45	45	763	887	1020	1169	1339	30
	50	1038	1206	1387	1589	1819	39
	55	1336	1550	1782	2041	2336	49
	60	1647	1908	2191	2510	2872	58
	65	1961	2269	2604	2982	3412	68
	70	2274	2626	3013	3449	3945	77
	75	2578	2974	3410	3903	4465	86
50	50	803	927	1064	1218	1393	30
	55	1057	1221	1400	1603	1835	38
	60	1330	1535	1761	2016	2306	47
	65	1613	1861	2134	2442	2794	56
	70	1901	2191	2511	2874	3288	64
	75	2187	2519	2887	3304	3778	73
	80	2468	2841	3255	3724	4259	81
55	55	835	960	1100	1258	1439	30
	60	1071	1232	1411	1615	1847	38
	65	1322	1521	1742	1994	2280	45
	70	1582	1820	2085	2386	2728	53
	75	1847	2124	2432	2783	3183	61
	80	2111	2427	2779	3180	3636	69
60	60	861	987	1130	1293	1479	30
	65	1080	1240	1420	1625	1858	37
	70	1313	1508	1726	1975	2258	44
	75	1554	1784	2043	2337	2672	51
	80	1799	2065	2364	2705	3093	58
65	65	882	1011	1157	1323	1513	30
	70	1088	1247	1427	1633	1867	36
	75	1305	1496	1712	1958	2239	43
	80	1529	1753	2006	2295	2624	50
70	70	901	1031	1180	1349	1542	30
	75	1094	1253	1434	1639	1874	36
	80	1297	1486	1700	1944	2223	42
75	75	917	1049	1200	1372	1569	30
	80	1099	1258	1439	1645	1881	35
80	80	931	1065	1218	1392	1592	30

Table 45.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of loblolly leaf pine in the East Gulf, initial basal area (BT1) = 40 square fee

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
20	20	237	464	662	835	1003	40
	25	709	1115	1430	1716	2008	64
	30	1326	1862	2280	2681	3107	87
	35	1982	2603	3112	3622	4177	106
	40	2609	3288	3875	4484	5156	123
	45	3177	3898	4554	5251	6028	136
	50	3679	4432	5149	5923	6792	147
25	25	467	712	902	1077	1258	40
	30	944	1294	1572	1843	2133	59
	35	1490	1928	2294	2665	3071	78
	40	2050	2559	3007	3477	3996	95
	45	2587	3154	3678	4239	4865	110
	50	3083	3699	4292	4936	5659	123
	55	3532	4190	4845	5564	6374	134
30	30	670	889	1069	1249	1443	40
	35	1107	1403	1660	1924	2215	56
	40	1584	1953	2287	2640	3033	72
	45	2069	2502	2912	3353	3846	87
	50	2537	3029	3509	4033	4623	100
	55	2978	3521	4067	4668	5348	112
	60	3384	3973	4579	5252	6013	123
35	35	818	1014	1190	1376	1582	40
	40	1212	1473	1718	1980	2273	54
	45	1634	1958	2273	2615	2998	68
	50	2061	2445	2828	3249	3723	81
	55	2477	2917	3366	3862	4423	93
	60	2874	3364	3875	4443	5086	104
	65	3245	3782	4350	4984	5705	114
40	40	924	1105	1282	1476	1692	40
	45	1281	1520	1759	2021	2316	52
	50	1658	1955	2257	2590	2967	64
	55	2041	2392	2756	3162	3620	76
	60	2416	2819	3244	3719	4257	87
	65	2777	3229	3711	4252	4866	97
	70	3118	3616	4152	4755	5441	106

ble 45.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 40 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
45	45	1000	1174	1355	1555	1781	40
	50	1327	1553	1789	2052	2350	51
	55	1669	1947	2241	2569	2941	62
	60	2016	2344	2695	3088	3534	72
	65	2357	2735	3141	3597	4116	82
	70	2688	3112	3571	4089	4678	91
	75	3005	3472	3982	4558	5214	100
50	50	1058	1230	1414	1620	1855	40
	55	1359	1578	1813	2077	2377	50
	60	1672	1938	2226	2550	2918	59
	65	1989	2302	2642	3025	3461	69
	70	2303	2661	3052	3494	3997	78
	75	2609	3010	3451	3950	4518	87
	80	2903	3346	3835	4388	5019	95
55	55	1103	1275	1463	1675	1916	40
	60	1382	1597	1832	2097	2399	49
	65	1671	1929	2213	2533	2897	58
	70	1964	2264	2596	2971	3399	66
	75	2254	2597	2976	3406	3895	75
	80	2538	2921	3347	3830	4380	83
60	60	1140	1312	1504	1722	1969	40
	65	1400	1612	1847	2114	2418	48
	70	1668	1920	2200	2518	2880	56
	75	1940	2231	2556	2925	3345	64
	80	2209	2540	2910	3329	3807	72
65	65	1170	1344	1540	1762	2015	40
	70	1414	1624	1860	2128	2434	47
	75	1664	1912	2189	2505	2864	55
	80	1917	2202	2521	2884	3298	62
70	70	1196	1372	1571	1796	2054	40
	75	1425	1635	1871	2141	2448	47
	80	1660	1904	2180	2493	2851	54
75	75	1218	1396	1598	1827	2089	40
	80	1434	1644	1881	2151	2460	46
80	80	1238	1418	1622	1854	2120	40

Table 46.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 50 square fee

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
20	20	296	580	827	1043	1253	50
	25	828	1315	1692	2033	2381	76
	30	1500	2122	2604	3065	3553	99
	35	2193	2893	3463	4033	4651	119
	40	2838	3586	4230	4897	5632	134
	45	3410	4192	4900	5651	6488	147
	50	3908	4714	5478	6303	7228	157
25	25	567	879	1121	1341	1569	50
	30	1108	1538	1876	2203	2551	71
	35	1707	2226	2654	3087	3558	91
	40	2302	2886	3397	3929	4517	107
	45	2857	3493	4077	4700	5395	122
	50	3358	4037	4687	5391	6181	134
	55	3804	4519	5227	6004	6879	144
30	30	812	1098	1329	1556	1799	50
	35	1309	1680	1994	2315	2666	68
	40	1834	2277	2673	3088	3549	84
	45	2350	2856	3327	3833	4399	99
	50	2837	3396	3938	4528	5190	113
	55	3284	3890	4496	5163	5914	124
	60	3689	4337	5001	5736	6568	134
35	35	998	1255	1481	1716	1974	50
	40	1446	1774	2075	2394	2749	65
	45	1909	2302	2677	3082	3535	80
	50	2365	2817	3263	3749	4297	93
	55	2799	3305	3816	4380	5017	105
	60	3203	3757	4329	4965	5684	116
	65	3575	4173	4800	5502	6297	126
40	40	1133	1371	1597	1840	2112	50
	45	1538	1839	2133	2453	2812	63
	50	1953	2313	2675	3072	3520	76
	55	2362	2778	3204	3676	4210	88
	60	2754	3222	3709	4253	4869	99
	65	3123	3638	4184	4794	5487	109
	70	3467	4026	4625	5297	6061	119

Table 46.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 50 square feet.

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
45	45	1232	1460	1689	1940	2223	50
	50	1602	1886	2177	2498	2862	62
	55	1978	2317	2669	3062	3505	73
	60	2349	2740	3153	3614	4136	84
	65	2707	3147	3617	4144	4742	94
	70	3048	3534	4057	4646	5316	104
	75	3368	3896	4470	5118	5855	113
50	50	1308	1530	1763	2022	2316	50
	55	1648	1922	2211	2535	2902	61
	60	1992	2317	2663	3051	3492	71
	65	2333	2706	3107	3559	4072	81
	70	2663	3082	3537	4050	4633	91
	75	2978	3441	3947	4518	5168	99
	80	3278	3781	4335	4961	5675	107
55	55	1368	1588	1825	2091	2393	50
	60	1682	1950	2239	2565	2935	60
	65	2000	2314	2656	3042	3480	69
	70	2314	2674	3067	3512	4017	78
	75	2620	3023	3467	3968	4539	87
	80	2915	3359	3850	4406	5039	95
60	60	1416	1636	1877	2149	2459	50
	65	1708	1972	2262	2590	2963	59
	70	2003	2311	2650	3033	3469	68
	75	2296	2645	3032	3470	3969	76
	80	2581	2972	3405	3896	4456	84
65	65	1455	1677	1922	2199	2516	50
	70	1729	1991	2282	2611	2986	58
	75	2005	2307	2643	3024	3459	66
	80	2278	2620	3001	3433	3926	74
70	70	1489	1712	1961	2243	2566	50
	75	1746	2007	2298	2629	3007	58
	80	2004	2303	2637	3017	3450	65
75	75	1518	1742	1995	2282	2609	50
	80	1760	2020	2313	2645	3025	57
80	80	1543	1769	2025	2316	2648	50

Table 47.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) an projected total basal area (BT2) for natural even-aged stands of lon leaf pine in the East Gulf, initial basal area (BT1) = 60 square fe

Initial age (Years)	Final age	Site index					Projected basal are (sq. ft.
		50	60	70	80	90	
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
20	20	355	695	991	1251	1502	60
	25	940	1503	1938	2330	2731	87
	30	1657	2354	2894	3408	3953	111
	35	2375	3145	3768	4390	5064	129
	40	3031	3840	4532	5248	6036	144
	45	3604	4437	5188	5985	6871	155
	50	4096	4946	5749	6615	7586	165
25	25	667	1046	1339	1606	1879	60
	30	1264	1769	2164	2544	2948	82
	35	1905	2497	2983	3471	4002	102
	40	2524	3176	3742	4330	4978	118
	45	3089	3786	4422	5099	5853	132
	50	3591	4324	5023	5778	6625	144
	55	4032	4795	5548	6372	7301	153
30	30	953	1307	1588	1862	2155	60
	35	1502	1944	2313	2688	3098	79
	40	2064	2577	3029	3502	4025	96
	45	2602	3173	3701	4265	4895	111
	50	3099	3718	4315	4962	5689	123
	55	3548	4209	4867	5589	6403	134
	60	3948	4647	5359	6148	7040	144
35	35	1174	1496	1771	2055	2366	60
	40	1669	2063	2417	2792	3207	76
	45	2165	2623	3054	3517	4035	91
	50	2640	3155	3657	4204	4818	104
	55	3084	3649	4216	4840	5544	116
	60	3490	4100	4726	5421	6207	127
	65	3859	4509	5188	5947	6807	136
40	40	1339	1636	1911	2204	2531	60
	45	1784	2146	2494	2870	3291	74
	50	2228	2650	3067	3524	4038	87
	55	2655	3131	3614	4148	4751	100
	60	3057	3582	4127	4732	5418	111
	65	3429	4000	4601	5273	6035	120
	70	3771	4383	5035	5768	6600	129

Table 47.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 60 square feet

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
45	45	1462	1744	2022	2325	2665	60
	50	1867	2208	2552	2931	3358	73
	55	2268	2666	3074	3527	4039	85
	60	2656	3105	3575	4099	4692	96
	65	3024	3521	4048	4639	5309	106
	70	3368	3909	4490	5143	5884	115
	75	3687	4269	4899	5609	6417	123
50	50	1556	1830	2112	2424	2776	60
	55	1927	2256	2598	2980	3412	71
	60	2294	2675	3077	3527	4037	82
	65	2650	3080	3539	4055	4640	92
	70	2990	3465	3979	4556	5213	102
	75	3310	3828	4392	5028	5752	111
	80	3609	4167	4778	5469	6255	118
55	55	1630	1900	2186	2506	2869	60
	60	1972	2293	2636	3020	3456	70
	65	2311	2681	3079	3526	4035	80
	70	2641	3056	3507	4016	4594	90
	75	2956	3415	3917	4484	5129	99
	80	3255	3755	4305	4927	5635	107
60	60	1690	1959	2249	2576	2948	60
	65	2008	2324	2667	3054	3494	70
	70	2323	2684	3079	3525	4032	79
	75	2629	3034	3478	3981	4554	87
	80	2924	3370	3862	4420	5055	96
65	65	1739	2008	2303	2637	3017	60
	70	2036	2349	2693	3083	3527	69
	75	2330	2686	3078	3523	4029	77
	80	2617	3013	3453	3951	4518	85
70	70	1780	2051	2350	2690	3076	60
	75	2059	2371	2716	3108	3555	68
	80	2335	2686	3077	3521	4026	76
75	75	1816	2088	2391	2736	3129	60
	80	2079	2389	2736	3130	3579	68
80	80	1847	2120	2428	2777	3175	60

Table 48.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) an projected total basal area (BT2) for natural even-aged stands of lon leaf pine in the East Gulf, initial basal area (BT1) = 70 square fe

Initial age (Years)	Final age	Site index					Projected basal are (sq. ft.
		50	60	70	80	90	
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
20	20	414	810	1156	1458	1752	70
	25	1047	1680	2170	2612	3062	98
	30	1799	2567	3159	3722	4317	121
	35	2538	3369	4039	4707	5431	139
	40	3200	4061	4795	5553	6388	152
	45	3771	4647	5436	6272	7201	163
	50	4256	5143	5979	6881	7891	171
25	25	767	1212	1557	1870	2189	70
	30	1412	1990	2439	2870	3327	93
	35	2087	2747	3286	3826	4412	112
	40	2723	3437	4052	4690	5394	128
	45	3294	4045	4727	5452	6259	142
	50	3794	4574	5315	6115	7012	152
	55	4228	5032	5823	6689	7665	161
30	30	1092	1515	1847	2168	2511	70
	35	1687	2198	2620	3047	3512	89
	40	2278	2856	3361	3887	4469	106
	45	2832	3462	4041	4658	5346	121
	50	3333	4007	4651	5350	6134	133
	55	3780	4490	5193	5964	6833	143
	60	4174	4916	5671	6507	7451	152
35	35	1350	1735	2061	2393	2757	70
	40	1883	2341	2748	3176	3650	87
	45	2404	2924	3408	3926	4505	102
	50	2893	3466	4019	4622	5298	115
	55	3341	3960	4577	5255	6020	126
	60	3746	4405	5079	5826	6672	136
	65	4108	4804	5529	6338	7255	145
40	40	1544	1900	2225	2568	2950	70
	45	2022	2444	2843	3274	3756	85
	50	2488	2968	3438	3951	4529	98
	55	2926	3458	3994	4585	5252	110
	60	3332	3911	4507	5169	5919	121
	65	3703	4324	4975	5702	6527	130
	70	4040	4699	5400	6186	7079	139

Table 48.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 70 square feet

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
45	45	1690	2028	2355	2709	3107	70
	50	2123	2521	2917	3351	3840	83
	55	2544	2997	3459	3969	4546	95
	60	2942	3446	3969	4551	5211	106
	65	3314	3864	4444	5093	5829	116
	70	3657	4249	4882	5592	6398	125
	75	3972	4602	5283	6049	6920	133
50	50	1802	2129	2460	2825	3236	70
	55	2198	2581	2976	3413	3909	82
	60	2582	3017	3473	3981	4558	93
	65	2948	3431	3945	4520	5173	103
	70	3292	3820	4387	5024	5749	112
	75	3611	4180	4797	5493	6284	121
	80	3907	4514	5177	5926	6779	128
55	55	1890	2212	2547	2921	3345	70
	60	2255	2628	3023	3465	3966	81
	65	2609	3032	3484	3991	4567	91
	70	2948	3416	3922	4491	5139	100
	75	3268	3779	4335	4963	5678	109
	80	3567	4118	4722	5405	6182	117
60	60	1962	2281	2621	3003	3437	70
	65	2300	2667	3063	3509	4015	80
	70	2629	3042	3491	3998	4574	89
	75	2944	3401	3901	4465	5108	98
	80	3243	3741	4289	4908	5614	106
65	65	2021	2339	2685	3074	3517	70
	70	2336	2700	3097	3546	4056	79
	75	2643	3050	3497	4003	4579	88
	80	2938	3387	3881	4442	5080	96
70	70	2070	2389	2739	3136	3587	70
	75	2366	2727	3126	3578	4092	79
	80	2654	3056	3502	4007	4583	87
75	75	2113	2433	2788	3190	3648	70
	80	2391	2751	3152	3606	4124	78
80	80	2149	2471	2830	3238	3703	70

Table 49.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 80 square fee

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
20	20	472	925	1320	1666	2001	80
	25	1148	1849	2392	2880	3377	108
	30	1930	2762	3403	4011	4653	130
	35	2684	3570	4283	4993	5761	147
	40	3350	4256	5028	5824	6700	160
	45	3917	4832	5653	6522	7489	169
	50	4394	5313	6178	7111	8155	177
25	25	866	1379	1775	2134	2500	80
	30	1554	2202	2704	3183	3690	103
	35	2256	2981	3569	4157	4795	122
	40	2905	3675	4336	5020	5773	138
	45	3478	4278	5001	5768	6622	150
	50	3974	4796	5573	6413	7354	160
	55	4399	5240	6065	6968	7984	168
30	30	1232	1722	2105	2474	2867	80
	35	1865	2442	2916	3394	3913	100
	40	2479	3118	3673	4250	4887	116
	45	3043	3728	4354	5021	5763	130
	50	3546	4268	4957	5702	6538	142
	55	3987	4741	5485	6300	7219	152
	60	4373	5155	5948	6824	7815	160
35	35	1525	1975	2350	2731	3147	80
	40	2090	2611	3069	3549	4079	97
	45	2631	3209	3743	4313	4950	112
	50	3128	3754	4356	5010	5744	125
	55	3576	4244	4907	5636	6456	136
	60	3976	4681	5398	6193	7092	145
	65	4331	5068	5834	6688	7656	153
40	40	1747	2164	2538	2932	3369	80
	45	2253	2734	3184	3667	4208	95
	50	2734	3270	3791	4358	4996	108
	55	3180	3764	4350	4994	5721	120
	60	3586	4214	4858	5572	6380	130
	65	3953	4619	5316	6094	6975	139
	70	4282	4984	5728	6563	7510	147

le 49.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 80 square feet.

rtial age (Years)	Final age	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VOM (cubic feet,o b.,/acre)					BT2
45	45	1916	2311	2687	3093	3548	80
	50	2372	2826	3273	3761	4311	93
	55	2806	3314	3826	4392	5031	105
	60	3211	3766	4340	4977	5698	116
	65	3583	4182	4811	5514	6311	126
	70	3922	4560	5240	6003	6869	134
	75	4231	4905	5631	6448	7377	142
50	50	2046	2428	2808	3225	3696	80
	55	2462	2899	3344	3838	4395	92
	60	2858	3346	3853	4418	5057	103
	65	3229	3763	4328	4959	5676	113
	70	3573	4150	4767	5460	6248	122
	75	3889	4505	5171	5921	6774	130
	80	4179	4831	5541	6343	7256	138
55	55	2150	2523	2908	3336	3820	80
	60	2531	2957	3403	3901	4465	91
	65	2896	3370	3873	4438	5079	101
	70	3239	3758	4315	4942	5655	111
	75	3559	4119	4727	5412	6191	119
	80	3856	4454	5108	5847	6688	127
60	60	2233	2602	2993	3430	3926	80
	65	2586	3004	3452	3954	4525	90
	70	2924	3388	3890	4454	5096	100
	75	3244	3751	4303	4926	5635	108
	80	3543	4090	4690	5368	6140	116
65	65	2302	2669	3065	3511	4017	80
	70	2631	3044	3494	4000	4576	89
	75	2946	3403	3903	4468	5111	98
	80	3245	3743	4291	4911	5617	106
70	70	2360	2727	3128	3581	4097	80
	75	2667	3078	3530	4040	4621	89
	80	2963	3415	3914	4479	5123	97
75	75	2409	2777	3183	3643	4167	80
	80	2698	3107	3561	4075	4660	88
80	80	2451	2821	3232	3698	4229	80

Table 50.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) a
projected total basal area (BT2) for natural even-aged stands of lo
leaf pine in the East Gulf, initial basal area (BT1) = 90 square f

Initial age	Final age	Site index					Projecte basal ar
(Years)		50	60	70	80	90	(sq. ft
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
20	20	531	1041	1485	1874	2250	90
	25	1244	2011	2604	3136	3678	118
	30	2052	2944	3629	4279	4965	139
	35	2817	3753	4506	5253	6062	155
	40	3484	4432	5237	6067	6980	166
	45	4046	4995	5846	6746	7746	175
	50	4516	5464	6354	7314	8388	182
25	25	966	1545	1993	2397	2810	90
	30	1691	2406	2958	3484	4041	113
	35	2415	3200	3834	4467	5154	131
	40	3073	3894	4597	5323	6122	146
	45	3646	4489	5250	6056	6953	157
	50	4135	4995	5806	6681	7662	166
	55	4552	5425	6281	7215	8268	174
30	30	1371	1929	2364	2780	3222	90
	35	2037	2679	3203	3729	4301	110
	40	2669	3367	3969	4593	5282	126
	45	3239	3976	4646	5357	6150	139
	50	3740	4508	5237	6025	6909	150
	55	4176	4969	5750	6605	7568	159
	60	4553	5369	6196	7110	8142	166
35	35	1698	2213	2639	3069	3538	90
	40	2291	2873	3381	3911	4496	107
	45	2846	3480	4062	4682	5374	121
	50	3347	4024	4672	5373	6161	134
	55	3793	4507	5212	5987	6859	144
	60	4187	4932	5690	6528	7475	153
	65	4533	5307	6110	7005	8019	160
40	40	1950	2427	2851	3295	3787	90
	45	2477	3016	3516	4051	4649	105
	50	2970	3559	4129	4748	5443	118
	55	3418	4053	4685	5379	6163	129
	60	3821	4495	5184	5947	6809	139
	65	4182	4891	5630	6453	7387	147
	70	4503	5243	6028	6906	7903	155

Table 50.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 90 square feet

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
45	45	2141	2593	3019	3477	3989	90
	50	2615	3124	3621	4162	4771	103
	55	3058	3618	4179	4798	5496	115
	60	3465	4069	4690	5380	6160	126
	65	3834	4479	5154	5907	6761	135
	70	4167	4848	5572	6384	7305	143
	75	4467	5181	5949	6813	7795	150
50	50	2290	2726	3155	3626	4155	90
	55	2720	3210	3706	4253	4871	102
	60	3123	3662	4219	4838	5539	113
	65	3495	4078	4692	5377	6154	123
	70	3836	4460	5124	5870	6717	131
	75	4147	4807	5518	6319	7229	139
	80	4430	5123	5877	6727	7695	146
55	55	2408	2833	3269	3751	4295	90
	60	2802	3279	3775	4329	4956	101
	65	3172	3696	4250	4870	5574	111
	70	3516	4083	4690	5372	6147	120
	75	3833	4440	5096	5835	6675	128
	80	4125	4768	5468	6260	7160	136
60	60	2503	2923	3364	3856	4415	90
	65	2867	3335	3834	4393	5027	100
	70	3210	3723	4276	4897	5603	110
	75	3530	4085	4688	5367	6140	118
	80	3827	4420	5070	5803	6637	126
65	65	2582	2999	3446	3948	4517	90
	70	2920	3383	3884	4448	5089	99
	75	3239	3745	4297	4919	5627	108
	80	3539	4085	4684	5361	6132	116
70	70	2648	3065	3517	4027	4607	90
	75	2963	3424	3927	4495	5142	99
	80	3263	3764	4315	4938	5648	107
75	75	2704	3121	3579	4097	4686	90
	80	3000	3459	3964	4537	5189	98
80	80	2753	3171	3634	4158	4756	90

Table 51.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 100 square feet

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
20	20	590	1156	1649	2081	2500	100
	25	1337	2166	2807	3383	3968	127
	30	2166	3113	3842	4530	5257	147
	35	2939	3922	4710	5492	6339	162
	40	3606	4591	5427	6288	7234	172
	45	4163	5143	6020	6946	7976	181
	50	4625	5599	6512	7495	8596	187
25	25	1065	1711	2211	2661	3119	100
	30	1823	2603	3204	3776	4380	123
	35	2565	3406	4085	4761	5493	140
	40	3228	4098	4839	5604	6447	154
	45	3799	4682	5477	6319	7255	164
	50	4282	5175	6017	6924	7941	172
	55	4690	5592	6475	7439	8524	179
30	30	1510	2136	2622	3086	3578	100
	35	2204	2909	3482	4055	4678	119
	40	2850	3603	4250	4919	5658	135
	45	3423	4207	4918	5673	6512	147
	50	3920	4729	5495	6323	7251	157
	55	4348	5178	5992	6884	7888	166
	60	4715	5564	6422	7369	8439	172
35	35	1872	2452	2928	3407	3929	100
	40	2487	3129	3685	4264	4903	117
	45	3051	3739	4366	5035	5779	131
	50	3554	4278	4968	5716	6554	142
	55	3995	4751	5496	6313	7233	152
	60	4381	5164	5958	6836	7829	160
	65	4717	5525	6363	7295	8350	167
40	40	2151	2690	3164	3658	4205	100
	45	2696	3291	3840	4426	5080	115
	50	3195	3837	4453	5122	5872	127
	55	3643	4325	5002	5744	6581	138
	60	4042	4758	5489	6297	7210	147
	65	4394	5142	5920	6787	7769	155
	70	4706	5482	6303	7221	8264	162

Table 51.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 100 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
45	45	2366	2876	3351	3860	4430	100
	50	2853	3416	3962	4555	5222	113
	55	3301	3911	4520	5190	5945	125
	60	3706	4357	5024	5763	6599	135
	65	4070	4758	5476	6277	7185	143
	70	4395	5117	5881	6738	7711	151
	75	4686	5437	6244	7151	8181	157
50	50	2533	3023	3503	4026	4615	100
	55	2973	3515	4060	4661	5339	112
	60	3379	3967	4573	5244	6005	123
	65	3750	4379	5039	5775	6611	132
	70	4085	4752	5462	6257	7160	140
	75	4389	5089	5843	6691	7656	147
	80	4662	5394	6188	7084	8104	154
55	55	2665	3144	3629	4165	4770	100
	60	3067	3595	4142	4749	5437	111
	65	3440	4012	4615	5289	6054	121
	70	3781	4395	5050	5784	6619	129
	75	4094	4744	5446	6236	7135	137
	80	4378	5062	5807	6648	7604	144
60	60	2773	3244	3735	4283	4903	100
	65	3143	3661	4210	4824	5521	110
	70	3487	4049	4651	5327	6095	119
	75	3804	4406	5057	5790	6624	127
	80	4097	4735	5430	6216	7111	135
65	65	2861	3329	3827	4384	5017	100
	70	3204	3717	4268	4888	5593	109
	75	3524	4079	4680	5358	6130	118
	80	3822	4414	5062	5794	6628	126
70	70	2936	3402	3906	4472	5117	100
	75	3255	3764	4319	4944	5656	109
	80	3555	4104	4706	5386	6160	117
75	75	2999	3465	3975	4550	5205	100
	80	3299	3806	4363	4993	5711	108
80	80	3054	3521	4036	4619	5283	100

Table 52.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) an
projected total basal area (BT2) for natural even-aged stands of lon
leaf pine in the East Gulf, initial basal area (BT1) = 110 square fe

Initial age	Final age	Site index					Projected basal are
(Years)		50	60	70	80	90	(sq. ft.
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
20	20	648	1271	1813	2288	2749	110
	25	1427	2315	3003	3620	4247	136
	30	2273	3273	4041	4767	5532	155
	35	3052	4078	4900	5714	6595	168
	40	3717	4738	5602	6490	7467	178
	45	4269	5277	6177	7129	8186	185
	50	4724	5720	6654	7659	8784	191
25	25	1164	1877	2429	2925	3429	110
	30	1952	2794	3443	4058	4708	132
	35	2707	3603	4323	5039	5815	148
	40	3374	4288	5066	5867	6750	161
	45	3940	4861	5688	6562	7535	171
	50	4416	5341	6210	7147	8197	178
	55	4815	5744	6651	7642	8757	184
30	30	1649	2343	2880	3392	3933	110
	35	2367	3133	3753	4373	5044	129
	40	3022	3828	4518	5231	6017	143
	45	3595	4425	5175	5969	6853	155
	50	4087	4935	5736	6600	7569	164
	55	4506	5370	6216	7141	8183	172
	60	4864	5742	6628	7606	8711	178
35	35	2045	2690	3217	3745	4319	110
	40	2678	3378	3982	4609	5300	126
	45	3248	3987	4659	5373	6168	139
	50	3749	4519	5249	6040	6925	150
	55	4184	4980	5762	6619	7584	159
	60	4561	5379	6207	7123	8157	167
	65	4887	5727	6595	7561	8656	173
40	40	2353	2953	3476	4022	4624	110
	45	2911	3561	4158	4793	5502	124
	50	3413	4105	4766	5482	6285	136
	55	3858	4584	5303	6091	6978	147
	60	4249	5006	5775	6626	7588	155
	65	4592	5377	6191	7098	8125	162
	70	4893	5703	6557	7513	8598	168

Table 52.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 110 square feet

Initial age	Final age	Site index					Projected basal area
	(Years)	50	60	70	80	90	(sq. ft.)
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
45	45	2590	3158	3682	4244	4870	110
	50	3086	3703	4296	4941	5664	123
	55	3535	4194	4849	5568	6379	134
	60	3936	4632	5342	6128	7018	143
	65	4292	5022	5781	6627	7586	151
	70	4609	5368	6171	7070	8091	158
	75	4889	5676	6518	7465	8541	164
50	50	2775	3321	3850	4426	5074	110
	55	3222	3815	4409	5062	5799	122
	60	3627	4263	4915	5638	6456	132
	65	3993	4667	5372	6157	7048	141
	70	4321	5030	5781	6624	7580	148
	75	4616	5355	6149	7042	8057	155
	80	4879	5647	6479	7417	8485	161
55	55	2922	3454	3989	4579	5245	110
	60	3328	3906	4502	5163	5912	121
	65	3699	4319	4970	5696	6520	130
	70	4036	4694	5395	6180	7072	138
	75	4341	5034	5779	6618	7572	146
	80	4616	5340	6127	7014	8023	152
60	60	3042	3565	4106	4709	5391	110
	65	3414	3982	4580	5249	6008	120
	70	3756	4365	5015	5745	6574	129
	75	4069	4715	5413	6198	7091	136
	80	4354	5034	5775	6611	7562	143
65	65	3140	3658	4207	4821	5517	110
	70	3484	4046	4647	5323	6091	119
	75	3802	4403	5054	5787	6620	127
	80	4094	4732	5428	6213	7107	135
70	70	3223	3739	4294	4918	5627	110
	75	3543	4101	4706	5388	6163	118
	80	3840	4436	5087	5823	6661	126
75	75	3293	3809	4370	5003	5723	110
	80	3593	4148	4756	5444	6227	118
80	80	3354	3870	4437	5078	5809	110

Table 53.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) an projected total basal area (BT2) for natural even-aged stands of lon leaf pine in the East Gulf, initial basal area (BT1) = 120 square fe

Initial age (Years)	Final age	Site index					Projected basal are
		50	60	70	80	90	(sq. ft.
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
20	20	707	1386	1977	2496	2998	120
	25	1513	2460	3192	3849	4516	145
	30	2374	3424	4230	4990	5792	162
	35	3157	4224	5076	5921	6833	174
	40	3820	4872	5762	6677	7682	183
	45	4366	5399	6322	7296	8378	190
	50	4814	5831	6783	7808	8955	195
25	25	1264	2043	2646	3188	3739	120
	30	2076	2980	3674	4333	5027	141
	35	2843	3789	4549	5304	6121	156
	40	3510	4466	5278	6114	7034	168
	45	4072	5027	5883	6789	7795	176
	50	4540	5493	6388	7353	8433	183
	55	4930	5883	6813	7828	8971	189
30	30	1788	2550	3138	3697	4288	120
	35	2525	3351	4018	4682	5402	138
	40	3187	4043	4775	5529	6360	152
	45	3758	4631	5417	6249	7175	162
	50	4243	5128	5961	6860	7867	171
	55	4654	5548	6424	7380	8457	178
	60	5002	5907	6819	7825	8962	183
35	35	2218	2928	3506	4083	4709	120
	40	2865	3622	4273	4947	5689	135
	45	3438	4226	4941	5698	6542	148
	50	3935	4747	5516	6347	7279	158
	55	4362	5195	6012	6907	7914	166
	60	4729	5580	6440	7390	8463	173
	65	5045	5913	6811	7809	8939	179
40	40	2554	3216	3789	4384	5041	120
	45	3120	3826	4469	5153	5915	134
	50	3623	4363	5067	5830	6685	145
	55	4062	4832	5590	6421	7357	155
	60	4445	5240	6047	6938	7945	162
	65	4778	5597	6445	7389	8459	169
	70	5068	5909	6795	7786	8910	174

Table 53.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 120 square feet

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
45	45	2814	3439	4014	4627	5311	120
	50	3315	3984	4625	5320	6099	132
	55	3761	4468	5167	5935	6800	143
	60	4156	4895	5647	6479	7419	152
	65	4504	5272	6070	6959	7966	159
	70	4810	5604	6444	7383	8449	165
	75	5080	5898	6775	7759	8877	171
50	50	3017	3618	4197	4826	5533	120
	55	3466	4110	4752	5456	6251	131
	60	3868	4551	5248	6021	6894	141
	65	4227	4944	5692	6524	7468	149
	70	4546	5294	6086	6973	7980	156
	75	4830	5606	6438	7373	8436	162
	80	5083	5884	6752	7730	8843	168
55	55	3179	3764	4349	4993	5720	120
	60	3585	4213	4857	5571	6379	130
	65	3952	4618	5315	6092	6974	139
	70	4281	4983	5727	6561	7509	147
	75	4577	5310	6097	6983	7989	154
	80	4843	5604	6430	7361	8421	160
60	60	3310	3885	4477	5135	5879	120
	65	3681	4298	4946	5668	6488	129
	70	4019	4674	5371	6153	7041	138
	75	4324	5014	5757	6592	7542	145
	80	4600	5322	6105	6989	7995	152
65	65	3419	3988	4587	5257	6016	120
	70	3761	4371	5022	5752	6582	129
	75	4074	4721	5419	6205	7099	137
	80	4358	5040	5781	6618	7570	143
70	70	3510	4076	4682	5363	6136	120
	75	3827	4433	5088	5826	6665	128
	80	4119	4761	5460	6251	7150	135
75	75	3587	4152	4765	5456	6242	120
	80	3884	4487	5146	5890	6737	128
80	80	3654	4220	4839	5538	6335	120

Table 54.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) an projected total basal area (BT2) for natural even-aged stands of lon leaf pine in the East Gulf, initial basal area (BT1) = 130 square fe

Initial age	Final age	Site index					Projected basal are
(Years)		50	60	70	80	90	(sq. ft.
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
20	20	766	1501	2142	2703	3247	130
	25	1597	2600	3376	4071	4777	154
	30	2471	3568	4409	5202	6038	169
	35	3256	4360	5241	6114	7057	180
	40	3915	4997	5911	6850	7881	188
	45	4455	5512	6455	7450	8555	194
	50	4896	5933	6902	7945	9112	198
25	25	1363	2209	2864	3452	4049	130
	30	2197	3160	3900	4600	5338	150
	35	2972	3968	4766	5558	6414	164
	40	3638	4635	5479	6348	7303	174
	45	4194	5182	6066	7000	8038	182
	50	4654	5635	6554	7544	8652	188
	55	5036	6012	6963	8000	9168	193
30	30	1926	2756	3396	4002	4643	130
	35	2679	3564	4276	4985	5752	147
	40	3345	4251	5022	5816	6691	159
	45	3913	4826	5647	6515	7481	169
	50	4390	5309	6173	7104	8147	177
	55	4791	5715	6617	7603	8712	183
	60	5129	6060	6996	8028	9195	188
35	35	2391	3166	3794	4420	5099	130
	40	3048	3861	4557	5277	6070	145
	45	3621	4457	5212	6013	6903	156
	50	4111	4965	5771	6641	7616	165
	55	4529	5398	6248	7179	8226	173
	60	4886	5768	6658	7641	8750	179
	65	5191	6087	7012	8040	9204	184
40	40	2755	3478	4101	4747	5459	130
	45	3326	4086	4775	5507	6322	143
	50	3826	4613	5360	6167	7071	154
	55	4258	5069	5866	6738	7721	162
	60	4630	5462	6304	7234	8284	169
	65	4953	5804	6685	7664	8774	175
	70	5232	6102	7017	8041	9202	180

Table 54.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 130 square feet

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
45	45	3037	3721	4345	5010	5751	130
	50	3540	4261	4948	5692	6527	142
	55	3981	4734	5477	6291	7208	151
	60	4368	5148	5940	6815	7805	159
	65	4705	5510	6346	7275	8328	166
	70	5000	5828	6702	7679	8788	172
	75	5259	6108	7016	8035	9194	177
50	50	3259	3915	4544	5226	5992	130
	55	3706	4401	5089	5845	6696	141
	60	4102	4831	5572	6393	7321	150
	65	4452	5211	6000	6878	7873	157
	70	4761	5547	6377	7307	8362	164
	75	5034	5844	6712	7688	8796	169
	80	5275	6109	7010	8026	9181	174
55	55	3435	4073	4709	5407	6194	130
	60	3838	4515	5207	5973	6840	140
	65	4198	4910	5652	6479	7416	148
	70	4518	5262	6049	6930	7930	155
	75	4804	5575	6402	7332	8389	161
	80	5058	5855	6719	7692	8799	167
60	60	3578	4205	4848	5561	6367	130
	65	3945	4611	5306	6082	6962	139
	70	4275	4976	5719	6552	7497	147
	75	4571	5303	6089	6974	7979	154
	80	4837	5597	6422	7353	8411	159
65	65	3697	4317	4967	5693	6516	130
	70	4034	4692	5392	6177	7068	138
	75	4339	5031	5776	6615	7568	146
	80	4614	5338	6124	7011	8020	152
70	70	3796	4413	5070	5808	6646	130
	75	4108	4761	5466	6259	7161	138
	80	4392	5079	5826	6669	7629	145
75	75	3881	4496	5160	5909	6760	130
	80	4171	4822	5531	6331	7242	137
80	80	3954	4569	5240	5998	6861	130

Table 55.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 140 square fee

Initial age	Final age	Site index					Projected basal area
(Years)		50	60	70	80	90	(sq. ft.)
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
20	20	824	1616	2306	2910	3496	140
	25	1678	2735	3554	4287	5030	162
	30	2562	3704	4579	5404	6273	176
	35	3349	4488	5397	6296	7267	186
	40	4004	5114	6050	7011	8067	192
	45	4538	5617	6578	7592	8719	197
	50	4972	6026	7012	8071	9258	201
25	25	1462	2375	3082	3715	4358	140
	30	2315	3336	4120	4860	5640	158
	35	3096	4139	4973	5800	6695	171
	40	3760	4794	5669	6568	7557	180
	45	4310	5328	6238	7199	8267	187
	50	4762	5767	6708	7722	8856	192
	55	5135	6131	7101	8160	9351	197
30	30	2065	2963	3654	4308	4998	140
	35	2831	3773	4529	5280	6094	155
	40	3498	4450	5259	6092	7009	167
	45	4060	5012	5866	6769	7772	176
	50	4529	5480	6373	7335	8412	183
	55	4920	5871	6799	7812	8952	188
	60	5248	6202	7161	8218	9412	192
35	35	2563	3404	4082	4758	5489	140
	40	3227	4095	4837	5601	6443	154
	45	3797	4680	5475	6316	7252	164
	50	4280	5173	6015	6922	7938	172
	55	4688	5591	6473	7436	8521	179
	60	5034	5946	6864	7877	9021	184
	65	5329	6250	7200	8256	9451	189
40	40	2955	3740	4414	5110	5877	140
	45	3528	4341	5075	5854	6721	152
	50	4022	4855	5643	6493	7446	162
	55	4445	5296	6130	7042	8069	170
	60	4807	5674	6549	7515	8606	176
	65	5118	6000	6911	7924	9072	181
	70	5386	6283	7226	8280	9477	186

Table 55.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 140 square feet.

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
45	45	3260	4002	4677	5393	6191	140
	50	3761	4533	5266	6059	6948	151
	55	4195	4993	5778	6637	7605	160
	60	4571	5392	6222	7140	8176	167
	65	4897	5738	6609	7577	8674	173
	70	5180	6041	6947	7960	9109	178
	75	5428	6306	7243	8296	9492	183
50	50	3500	4212	4891	5626	6451	140
	55	3943	4687	5422	6228	7136	150
	60	4330	5104	5888	6756	7737	158
	65	4670	5469	6297	7220	8264	165
	70	4967	5789	6657	7627	8729	171
	75	5227	6071	6974	7987	9138	176
	80	5458	6321	7254	8305	9501	180
55	55	3691	4383	5068	5821	6669	140
	60	4088	4814	5552	6370	7294	149
	65	4438	5195	5981	6856	7848	157
	70	4748	5531	6360	7287	8339	163
	75	5021	5830	6696	7668	8774	169
	80	5264	6095	6994	8008	9161	174
60	60	3846	4525	5218	5986	6855	140
	65	4206	4919	5663	6491	7430	148
	70	4526	5271	6059	6942	7944	155
	75	4811	5584	6412	7344	8402	162
	80	5065	5863	6728	7703	8811	167
65	65	3975	4646	5347	6129	7015	140
	70	4304	5009	5758	6596	7548	148
	75	4599	5335	6126	7016	8027	154
	80	4863	5628	6457	7393	8457	160
70	70	4083	4749	5458	6253	7155	140
	75	4386	5086	5840	6687	7651	147
	80	4660	5391	6185	7080	8099	154
75	75	4175	4839	5555	6361	7278	140
	80	4456	5154	5912	6768	7742	147
80	80	4254	4918	5641	6458	7387	140

Table 56.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 150 square fee

Initial age (Years)	Final age	Site index					Projected basal area (sq. ft.)
		50	60	70	80	90	
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
20	20	883	1731	2470	3117	3745	150
	25	1757	2867	3726	4496	5276	170
	30	2650	3835	4742	5597	6498	182
	35	3437	4609	5544	6468	7466	191
	40	4088	5223	6180	7163	8241	197
	45	4615	5715	6693	7726	8872	201
	50	5042	6113	7113	8189	9392	204
25	25	1562	2541	3299	3978	4668	150
	30	2431	3508	4334	5114	5936	166
	35	3215	4303	5173	6034	6964	178
	40	3876	4946	5849	6778	7799	186
	45	4418	5465	6400	7386	8482	192
	50	4862	5891	6853	7889	9048	197
	55	5226	6243	7231	8309	9522	200
30	30	2203	3169	3911	4613	5353	150
	35	2979	3977	4777	5570	6428	164
	40	3645	4643	5489	6359	7316	174
	45	4200	5190	6075	7011	8050	182
	50	4660	5642	6562	7553	8662	188
	55	5041	6018	6970	8009	9178	193
	60	5360	6336	7315	8396	9615	197
35	35	2736	3642	4371	5095	5879	150
	40	3402	4325	5111	5920	6810	162
	45	3968	4896	5729	6611	7590	172
	50	4442	5373	6248	7191	8247	179
	55	4840	5774	6686	7682	8803	185
	60	5174	6114	7058	8100	9277	190
	65	5458	6404	7377	8459	9684	194
40	40	3155	4002	4726	5472	6295	150
	45	3727	4592	5371	6196	7114	161
	50	4214	5091	5918	6811	7811	170
	55	4626	5515	6384	7335	8405	177
	60	4976	5876	6783	7784	8915	182
	65	5275	6186	7126	8171	9354	187
	70	5532	6454	7424	8507	9736	191

Table 56.--Current and projected merchantable cubic foot volumes,o.b.,(VOM) and projected total basal area (BT2) for natural even-aged stands of longleaf pine in the East Gulf, initial basal area (BT1) = 150 square feet.

Initial age (Years)	Final age	Site index 50	60	70	80	90	Projected basal area (sq. ft.)
A1	A2	VOM (cubic feet,o.b.,/acre)					BT2
45	45	3483	4283	5008	5776	6631	150
	50	3978	4801	5580	6420	7362	160
	55	4403	5245	6071	6974	7992	168
	60	4768	5627	6494	7452	8535	174
	65	5081	5957	6861	7867	9005	180
	70	5352	6243	7180	8227	9416	184
	75	5588	6493	7459	8543	9775	188
50	50	3741	4508	5237	6026	6909	150
	55	4176	4970	5751	6606	7569	159
	60	4553	5370	6197	7110	8143	166
	65	4880	5718	6585	7550	8643	173
	70	5164	6022	6925	7935	9081	178
	75	5413	6288	7223	8273	9466	182
	80	5631	6523	7486	8571	9806	186
55	55	3947	4692	5428	6234	7143	150
	60	4334	5108	5894	6762	7744	158
	65	4673	5473	6302	7225	8271	165
	70	4970	5793	6661	7633	8735	171
	75	5231	6075	6978	7992	9144	176
	80	5461	6324	7258	8310	9507	180
60	60	4114	4845	5589	6412	7342	150
	65	4463	5224	6015	6896	7893	158
	70	4772	5560	6392	7324	8381	164
	75	5044	5856	6726	7703	8814	170
	80	5285	6120	7023	8040	9198	174
65	65	4252	4974	5726	6564	7514	150
	70	4571	5323	6119	7011	8023	157
	75	4853	5633	6469	7409	8477	163
	80	5105	5910	6782	7764	8882	168
70	70	4369	5086	5846	6697	7664	150
	75	4661	5408	6210	7112	8137	157
	80	4922	5697	6537	7484	8561	162
75	75	4468	5182	5950	6814	7796	150
	80	4738	5482	6290	7201	8237	156
80	80	4553	5267	6042	6917	7912	150

Table 57.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age (Years)	Initial total basal area (Sq. ft.)	Initial sawtimber/total basal area ratio										
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.
A1	A2	BT1	BS2 (square feet/acre)										
20	25	20	6	11	17	22	25	28	30	32	34	36	37
		30	9	15	23	30	35	39	42	45	47	49	51
		40	11	18	29	37	43	48	53	56	59	62	64
		50	13	22	35	44	52	57	62	67	70	73	76
		60	15	25	40	51	59	66	72	76	81	84	87
		70	17	28	45	57	66	74	80	86	90	94	98
		80	18	31	50	63	73	82	89	95	100	104	108
		90	20	34	54	69	80	89	97	103	109	114	118
		100	21	37	58	74	86	96	104	111	117	123	127
		110	23	39	62	79	92	103	112	119	126	131	136
		120	24	42	66	84	98	109	119	127	134	140	145
		130	26	44	70	89	104	116	126	134	141	148	154
		140	27	46	74	94	109	122	132	141	149	156	162
		150	29	49	78	99	115	128	139	148	156	163	170
20	30	20	20	29	38	43	47	49	51	53	54	55	56
		30	26	37	49	56	61	64	66	68	70	71	73
		40	31	45	59	67	73	76	79	82	84	85	87
		50	36	51	68	77	83	87	91	94	96	98	99
		60	40	57	75	86	92	97	101	104	107	109	111
		70	43	62	82	94	101	106	111	114	117	119	121
		80	47	67	89	101	109	115	119	123	126	128	130
		90	50	72	95	108	116	123	127	131	134	137	139
		100	53	76	100	114	123	130	135	139	142	145	147
		110	56	80	106	120	130	137	142	146	150	153	155
		120	58	84	111	126	136	143	149	153	157	160	162
		130	61	87	115	131	142	149	155	160	163	167	169
		140	63	91	120	136	147	155	161	166	170	173	176
		150	65	94	124	141	152	161	167	172	176	179	182
20	35	20	41	52	61	65	68	70	71	72	73	73	74
		30	51	64	75	81	84	86	88	89	90	91	92
		40	59	74	87	93	97	100	102	103	105	106	106
		50	66	83	97	104	108	111	113	115	116	118	119
		60	72	90	106	113	118	121	124	125	127	128	129
		70	77	97	114	122	127	130	133	135	136	137	139
		80	82	103	120	129	134	138	141	143	144	146	147
		90	86	108	127	136	141	145	148	150	152	153	155
		100	90	113	133	142	148	152	155	157	159	161	162
		110	94	118	138	148	154	158	161	164	165	167	168
		120	97	122	143	153	160	164	167	170	171	173	174
		130	100	126	148	158	165	169	173	175	177	179	180
		140	103	130	152	163	170	174	178	180	182	184	186
		150	106	133	156	168	174	179	183	185	187	189	191

Table 57.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age	Initial total basal area	Initial sawtimber/total basal area ratio										
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
A1	A2	BT1	BS2 (square feet/acre)										
20	40	20	65	74	81	85	87	88	89	90	90	91	91
		30	77	89	98	101	104	105	106	107	108	108	109
		40	87	100	110	114	117	119	120	121	122	122	123
		50	95	110	120	125	128	130	131	132	133	134	134
		60	102	117	129	134	137	139	140	142	142	143	144
		70	108	124	136	142	145	147	149	150	151	152	152
		80	113	130	143	149	152	154	156	157	158	159	160
		90	118	136	149	155	159	161	163	164	165	166	166
		100	123	141	155	161	164	167	168	170	171	172	172
		110	127	145	160	166	170	172	174	175	176	177	178
		120	130	150	164	171	175	177	179	180	182	182	183
		130	134	153	168	175	179	182	184	185	186	187	188
		140	137	157	172	179	183	186	188	189	191	192	192
		150	140	161	176	183	187	190	192	194	195	196	197
20	45	20	86	94	99	102	103	104	104	105	105	106	106
		30	100	109	116	118	120	121	122	122	123	123	123
		40	111	121	128	131	133	134	134	135	136	136	136
		50	119	130	138	141	143	144	145	145	146	146	147
		60	126	138	146	149	151	152	153	154	155	155	155
		70	133	144	153	156	158	160	161	161	162	163	163
		80	138	150	159	163	165	166	167	168	169	169	169
		90	143	155	164	168	170	172	173	174	174	175	175
		100	147	160	169	173	176	177	178	179	180	180	181
		110	151	164	174	178	180	182	183	184	184	185	185
		120	154	168	178	182	184	186	187	188	189	189	190
		130	158	172	182	186	188	190	191	192	193	193	194
		140	161	175	185	190	192	194	195	196	196	197	197
		150	163	178	188	193	195	197	198	199	200	200	201
20	50	20	104	110	114	116	117	117	118	118	119	119	119
		30	119	126	130	132	133	134	134	135	135	135	135
		40	130	137	142	144	145	146	146	147	147	147	147
		50	138	146	151	153	154	155	156	156	156	157	157
		60	145	153	158	161	162	163	163	164	164	165	165
		70	151	159	165	167	168	169	170	170	171	171	171
		80	156	164	170	173	174	175	176	176	177	177	177
		90	160	169	175	178	179	180	181	181	182	182	182
		100	164	173	180	182	184	185	185	186	186	187	187
		110	168	177	184	186	188	189	189	190	190	191	191
		120	171	181	187	190	191	192	193	194	194	194	195
		130	174	184	190	193	195	196	196	197	197	198	198
		140	177	187	193	196	198	199	200	200	201	201	201
		150	179	190	196	199	201	202	202	203	203	204	204

Table 57.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age	Initial total basal area	Initial sawtimber/total basal area ratio										
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
A1	A2	BT1	BS2 (square feet/acre)										
25	30	20	5	8	14	18	21	24	26	28	30	32	33
		30	6	11	19	25	30	34	37	40	42	45	47
		40	8	14	24	31	37	42	47	50	54	57	59
		50	10	17	29	38	45	51	56	60	64	68	71
		60	11	20	33	44	52	59	65	70	75	79	82
		70	13	23	38	49	59	66	73	79	84	89	93
		80	14	25	42	55	65	74	81	88	93	99	103
		90	16	27	46	60	71	81	89	96	102	108	113
		100	17	30	50	65	77	88	96	104	111	117	123
		110	18	32	53	70	83	94	104	112	119	126	132
		120	19	34	57	75	89	101	111	120	128	135	141
		130	21	36	61	79	94	107	118	127	135	143	150
		140	22	38	64	84	100	113	124	134	143	151	158
		150	23	40	67	88	105	119	131	141	151	159	166
25	35	20	13	21	29	34	38	41	43	44	46	47	48
		30	18	27	39	46	50	54	57	59	61	63	64
		40	22	33	47	55	61	66	69	72	74	76	78
		50	25	39	54	64	71	76	80	83	86	89	91
		60	28	43	61	72	80	86	90	94	97	100	102
		70	31	48	68	80	88	95	100	104	107	110	112
		80	34	52	74	87	96	103	108	113	116	119	122
		90	36	56	79	93	103	111	116	121	125	128	131
		100	39	60	84	99	110	118	124	129	133	137	140
		110	41	63	89	105	116	125	131	137	141	145	148
		120	43	67	94	111	123	131	138	144	149	153	156
		130	45	70	99	116	129	138	145	151	156	160	164
		140	47	73	103	121	134	144	151	158	163	167	171
		150	49	76	107	126	140	150	158	164	169	174	178
25	40	20	28	38	47	52	55	57	59	60	62	62	63
		30	36	48	60	66	70	73	75	77	78	80	81
		40	42	57	71	78	83	86	89	91	93	94	95
		50	47	64	80	89	94	98	101	103	105	106	107
		60	52	71	88	98	104	108	111	113	115	117	118
		70	57	77	96	106	112	117	120	123	125	127	128
		80	61	82	103	113	120	125	129	132	134	136	138
		90	64	87	109	120	128	133	137	140	142	144	146
		100	68	92	115	127	134	140	144	147	150	152	154
		110	71	96	120	133	141	146	151	154	157	159	161
		120	74	100	125	138	147	153	157	161	163	166	168
		130	77	104	130	144	152	158	163	167	170	172	174
		140	80	107	134	149	158	164	169	173	176	178	180
		150	82	111	139	153	163	169	174	178	181	184	186

Table 57.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age	Initial total basal area	Initial sawtimber/total basal area ratio									
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
A1	A2	BT1	BS2 (square feet/acre)										
25	45	20	46	56	65	69	72	73	75	76	76	77	78
		30	57	69	80	85	88	90	92	93	94	95	96
		40	65	80	92	98	102	104	106	107	108	109	110
		50	72	89	102	109	113	115	117	119	120	121	122
		60	78	96	111	118	122	125	127	129	130	131	132
		70	84	103	119	126	131	134	136	138	139	141	142
		80	89	109	126	134	138	142	144	146	148	149	150
		90	93	114	132	140	145	149	151	153	155	156	157
		100	97	119	138	146	152	155	158	160	162	163	164
		110	101	124	143	152	158	161	164	166	168	169	171
		120	104	128	148	157	163	167	170	172	174	175	176
		130	108	132	153	162	168	172	175	177	179	181	182
		140	111	136	157	167	173	177	180	182	184	186	187
		150	114	140	161	171	178	182	185	187	189	191	192
25	50	20	65	74	81	85	87	88	89	90	90	91	91
		30	77	89	98	101	104	105	106	107	108	108	109
		40	87	100	110	114	117	119	120	121	122	122	123
		50	95	110	120	125	128	130	131	132	133	134	134
		60	102	117	129	134	137	139	140	142	142	143	144
		70	108	124	136	142	145	147	149	150	151	152	152
		80	113	130	143	149	152	154	156	157	158	159	160
		90	118	136	149	155	159	161	163	164	165	166	166
		100	123	141	155	161	164	167	168	170	171	172	172
		110	127	145	160	166	170	172	174	175	176	177	178
		120	130	150	164	171	175	177	179	180	182	182	183
		130	134	153	168	175	179	182	184	185	186	187	188
		140	137	157	172	179	183	186	188	189	191	192	192
		150	140	161	176	183	187	190	192	194	195	196	197
25	55	20	82	90	96	98	100	101	101	102	102	103	103
		30	96	106	112	115	117	118	119	119	120	120	121
		40	107	117	125	128	130	131	132	132	133	133	134
		50	115	126	135	138	140	141	142	143	144	144	144
		60	122	134	143	147	149	150	151	152	152	153	153
		70	128	141	150	154	156	158	159	159	160	161	161
		80	134	147	156	160	163	164	165	166	167	167	168
		90	138	152	162	166	168	170	171	172	173	173	174
		100	143	157	167	171	174	175	176	177	178	179	179
		110	147	161	171	176	178	180	181	182	183	184	184
		120	150	165	176	180	183	184	186	187	187	188	189
		130	153	169	180	184	187	189	190	191	192	192	193
		140	157	172	183	188	191	192	194	195	195	196	197
		150	159	175	186	191	194	196	197	198	199	200	200

Table S7.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age	Initial total basal area	Initial sawtimber/total basal area ratio										
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
A1	A2	BT1	BS2 (square feet/acre)										
30	35	20	4	7	11	15	19	21	24	26	28	29	31
		30	5	9	16	22	26	30	34	37	39	42	44
		40	7	12	21	28	34	39	43	47	50	53	56
		50	8	15	25	33	40	46	52	56	60	64	68
		60	9	17	29	39	47	54	60	66	70	75	79
		70	11	19	33	44	53	61	68	74	80	85	89
		80	12	21	37	49	59	68	76	83	89	95	100
		90	13	24	40	54	65	75	84	91	98	104	110
		100	14	26	44	59	71	82	91	99	107	113	119
		110	15	28	48	63	77	88	98	107	115	122	129
		120	16	30	51	68	82	94	105	115	123	131	138
		130	17	32	54	72	88	101	112	122	131	139	147
		140	18	33	57	77	93	107	119	129	139	148	155
		150	20	35	61	81	98	113	125	137	147	156	164
30	40	20	10	16	23	28	32	35	37	39	41	42	43
		30	13	21	32	38	43	47	50	53	55	57	58
		40	16	26	39	47	53	58	62	65	68	70	72
		50	19	31	46	55	63	68	73	76	79	82	84
		60	22	35	52	63	71	77	82	86	90	93	96
		70	24	39	58	70	79	86	91	96	100	103	106
		80	26	42	63	76	86	94	100	105	109	113	116
		90	28	46	68	83	93	102	108	114	118	122	126
		100	31	49	73	89	100	109	116	122	127	131	135
		110	32	52	78	94	106	116	123	130	135	139	143
		120	34	55	82	100	113	122	130	137	143	147	152
		130	36	58	86	105	118	129	137	144	150	155	159
		140	38	61	90	110	124	135	144	151	157	162	167
		150	40	63	94	115	129	141	150	158	164	170	174
30	45	20	20	29	38	43	47	49	51	53	54	55	56
		30	26	37	49	56	61	64	66	68	70	71	73
		40	31	45	59	67	73	76	79	82	84	85	87
		50	36	51	68	77	83	87	91	94	96	98	99
		60	40	57	75	86	92	97	101	104	107	109	111
		70	43	62	82	94	101	106	111	114	117	119	121
		80	47	67	89	101	109	115	119	123	126	128	130
		90	50	72	95	108	116	123	127	131	134	137	139
		100	53	76	100	114	123	130	135	139	142	145	147
		110	56	80	106	120	130	137	142	146	150	153	155
		120	58	84	111	126	136	143	149	153	157	160	162
		130	61	87	115	131	142	149	155	160	163	167	169
		140	63	91	120	136	147	155	161	166	170	173	176
		150	65	94	124	141	152	161	167	172	176	179	182

ble 57.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age	Initial total basal area	Initial sawtimber/total basal area ratio									
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Ai	A2	BT1	BS2 (square feet/acre)										
30	50	20	34	44	53	58	61	63	64	66	67	67	68
		30	42	55	67	73	77	79	81	83	84	85	86
		40	50	65	78	85	90	93	95	97	98	99	100
		50	56	73	88	96	101	104	107	109	110	111	113
		60	61	80	97	105	110	114	117	119	121	122	123
		70	66	86	104	113	119	123	126	128	130	132	133
		80	70	91	111	121	127	131	134	137	139	141	142
		90	74	97	117	128	134	139	142	145	147	149	150
		100	78	102	123	134	141	146	149	152	154	156	157
		110	81	106	129	140	147	152	156	159	161	163	164
		120	84	110	134	145	153	158	162	165	167	169	171
		130	87	114	138	151	158	164	168	171	173	175	177
		140	90	118	143	156	163	169	173	176	179	181	183
		150	93	121	147	160	168	174	178	182	184	186	188
30	55	20	49	59	68	72	74	76	77	78	79	79	80
		30	60	73	83	88	91	93	94	96	97	97	98
		40	69	83	95	101	104	107	108	110	111	111	112
		50	76	92	106	112	115	118	120	121	122	123	124
		60	83	100	114	121	125	128	130	131	133	134	134
		70	88	107	122	129	133	136	139	140	141	143	143
		80	93	113	129	136	141	144	146	148	149	151	152
		90	98	118	135	143	148	151	153	155	157	158	159
		100	102	123	141	149	154	158	160	162	163	165	166
		110	106	128	146	155	160	163	166	168	170	171	172
		120	109	132	151	160	165	169	172	174	175	177	178
		130	112	136	156	165	170	174	177	179	181	182	183
		140	116	140	160	169	175	179	182	184	186	187	188
		150	118	144	164	174	179	183	186	188	190	192	193
30	60	20	65	74	81	85	87	88	89	90	90	91	91
		30	77	89	98	101	104	105	106	107	108	108	109
		40	87	100	110	114	117	119	120	121	122	122	123
		50	95	110	120	125	128	130	131	132	133	134	134
		60	102	117	129	134	137	139	140	142	142	143	144
		70	108	124	136	142	145	147	149	150	151	152	152
		80	113	130	143	149	152	154	156	157	158	159	160
		90	118	136	149	155	159	161	163	164	165	166	166
		100	123	141	155	161	164	167	168	170	171	172	172
		110	127	145	160	166	170	172	174	175	176	177	178
		120	130	150	164	171	175	177	179	180	182	182	183
		130	134	153	168	175	179	182	184	185	186	187	188
		140	137	157	172	179	183	186	188	189	191	192	192
		150	140	161	176	183	187	190	192	194	195	196	197

Table 57.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age (Years)	Initial total basal area (Sq. ft.)	Initial sawtimber/total basal area ratio									
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
A1	A2	BT1	BS2 (square feet/acre)									
35	40	20	3	6	10	14	17	19	22	24	26	28
		30	4	8	14	20	24	28	31	34	37	40
		40	6	11	19	25	31	36	40	44	48	51
		50	7	13	22	30	37	43	49	53	58	62
		60	8	15	26	36	44	51	57	62	67	72
		70	9	17	30	40	50	58	65	71	77	82
		80	10	19	33	45	55	64	72	79	86	92
		90	11	21	37	50	61	71	80	87	95	101
		100	12	23	40	54	67	77	87	95	103	110
		110	13	25	43	59	72	84	94	103	112	119
		120	14	27	47	63	77	90	101	111	120	128
		130	15	28	50	68	83	96	108	118	128	137
		140	16	30	53	72	88	102	114	126	136	145
		150	17	32	56	76	93	108	121	133	143	153
35	45	20	8	13	20	24	28	31	33	35	37	38
		30	10	17	27	33	38	42	46	48	51	53
		40	13	22	33	42	48	53	57	60	63	65
		50	15	25	39	49	56	62	67	71	74	77
		60	18	29	45	56	64	71	76	81	85	88
		70	20	33	50	63	72	79	85	90	95	98
		80	22	36	55	69	79	87	94	99	104	108
		90	23	39	60	75	86	95	102	108	113	117
		100	25	42	65	80	92	102	109	116	122	126
		110	27	45	69	86	99	109	117	124	130	135
		120	28	47	73	91	105	115	124	131	138	143
		130	30	50	77	96	110	122	131	139	145	151
		140	32	52	81	101	116	128	138	146	153	159
		150	33	55	85	106	121	134	144	152	160	166
35	50	20	15	23	32	37	40	43	45	47	48	49
		30	20	30	42	49	53	57	60	62	64	65
		40	24	36	50	59	65	69	72	75	77	79
		50	28	42	58	68	75	80	83	86	89	91
		60	31	47	65	76	84	89	94	97	100	102
		70	35	52	72	84	92	98	103	107	110	113
		80	37	56	78	91	100	106	112	116	119	122
		90	40	60	84	98	107	114	120	124	128	131
		100	43	64	89	104	114	122	127	132	136	139
		110	45	68	94	110	120	128	135	140	144	147
		120	48	71	99	115	127	135	142	147	151	155
		130	50	75	104	121	133	141	148	154	158	162
		140	52	78	108	126	138	147	154	160	165	169
		150	54	81	112	131	144	153	160	166	171	176

e 57.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

ial age (Years)	Final age	Initial total basal area (Sq. ft.)	Initial sawtimber/total basal area ratio										
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
1	A2	BT1	BS2 (square feet/acre)										
5	55	20	26	35	45	50	53	55	57	58	59	60	61
		30	33	45	57	64	68	71	73	75	76	77	78
		40	39	53	68	75	80	84	86	88	90	91	93
		50	44	60	77	85	91	95	98	100	102	104	105
		60	49	67	85	94	101	105	108	111	113	115	116
		70	53	73	92	103	109	114	118	120	123	125	126
		80	57	78	99	110	117	122	126	129	132	134	136
		90	60	83	105	117	125	130	134	137	140	142	144
		100	63	87	111	123	131	137	141	145	148	150	152
		110	67	91	116	129	138	144	148	152	155	157	159
		120	69	95	121	135	144	150	155	159	162	164	166
		130	72	99	126	140	149	156	161	165	168	171	173
		140	75	103	131	145	155	162	167	171	174	177	179
		150	77	106	135	150	160	167	172	176	180	183	185
35	60	20	38	48	58	62	65	67	68	69	70	71	72
		30	47	60	72	77	81	83	85	87	88	89	89
		40	55	70	83	90	94	97	99	101	102	103	104
		50	62	78	93	101	105	108	111	112	114	115	116
		60	67	86	102	110	115	118	121	123	124	126	127
		70	72	92	110	118	123	127	130	132	134	135	136
		80	77	98	117	126	131	135	138	140	142	144	145
		90	81	103	123	132	138	143	146	148	150	151	153
		100	85	108	129	139	145	149	152	155	157	159	160
		110	88	113	134	145	151	156	159	161	164	165	167
		120	92	117	139	150	157	161	165	168	170	171	173
		130	95	121	144	155	162	167	171	173	176	177	179
		140	98	125	148	160	167	172	176	179	181	183	184
		150	101	128	153	165	172	177	181	184	186	188	190
35	65	20	51	62	70	74	76	78	79	80	80	81	81
		30	63	75	85	90	93	95	96	97	98	99	100
		40	72	86	98	103	106	108	110	111	112	113	114
		50	79	95	108	114	117	120	122	123	124	125	126
		60	85	103	117	123	127	129	131	133	134	135	136
		70	91	109	124	131	135	138	140	142	143	144	145
		80	96	116	131	138	143	146	148	150	151	152	153
		90	101	121	137	145	150	153	155	157	158	159	160
		100	105	126	143	151	156	159	161	163	165	166	167
		110	109	131	148	157	161	165	167	169	171	172	173
		120	112	135	153	162	167	170	173	175	176	178	179
		130	116	139	158	167	172	175	178	180	181	183	184
		140	119	143	162	171	176	180	183	185	186	188	189
		150	122	146	166	175	181	184	187	189	191	192	194

Table 57 --Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age	Initial total basal area	Initial sawtimber/total basal area ratio									
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
A1	A2	BT1	BS2 (square feet/acre)										
40	45	20	3	5	9	13	16	18	21	23	25	26	28
		30	4	7	13	18	22	26	29	33	35	38	40
		40	5	9	17	23	29	34	38	42	46	49	52
		50	6	12	21	28	35	41	46	51	55	60	63
		60	7	13	24	33	41	48	54	60	65	70	74
		70	8	15	28	38	47	55	62	68	74	80	85
		80	9	17	31	42	52	61	69	77	83	89	95
		90	10	19	34	47	58	68	77	85	92	99	105
		100	11	21	37	51	63	74	84	92	101	108	115
		110	12	23	40	55	69	80	91	100	109	117	124
		120	13	24	43	60	74	86	98	108	117	126	134
		130	14	26	46	64	79	92	104	115	125	134	143
		140	15	28	49	68	84	98	111	123	133	143	152
		150	16	29	52	72	89	104	117	130	141	151	161
40	50	20	6	11	17	22	25	28	30	32	34	36	37
		30	9	15	23	30	35	39	42	45	47	49	51
		40	11	18	29	37	43	48	53	56	59	62	64
		50	13	22	35	44	52	57	62	67	70	73	76
		60	15	25	40	51	59	66	72	76	81	84	87
		70	17	28	45	57	66	74	80	86	90	94	98
		80	18	31	50	63	73	82	89	95	100	104	108
		90	20	34	54	69	80	89	97	103	109	114	118
		100	21	37	58	74	86	96	104	111	117	123	127
		110	23	39	62	79	92	103	112	119	126	131	136
		120	24	42	66	84	98	109	119	127	134	140	145
		130	26	44	70	89	104	116	126	134	141	148	154
		140	27	46	74	94	109	122	132	141	149	156	162
		150	29	49	78	99	115	128	139	148	156	163	170
40	55	20	12	19	27	32	36	38	41	42	44	45	46
		30	16	25	36	43	48	51	54	57	59	61	62
		40	20	31	44	52	58	63	66	69	72	74	76
		50	23	36	51	61	68	73	77	81	84	86	88
		60	26	40	58	69	77	83	87	91	94	97	100
		70	28	44	64	76	85	91	97	101	104	108	110
		80	31	48	70	83	92	100	105	110	114	117	120
		90	33	52	75	89	100	107	113	118	123	126	129
		100	36	56	80	95	106	115	121	127	131	135	138
		110	38	59	85	101	113	122	129	134	139	143	147
		120	40	62	90	107	119	128	136	142	147	151	155
		130	42	65	94	112	125	135	142	149	154	158	162
		140	44	68	98	117	131	141	149	155	161	165	170
		150	46	71	102	122	136	147	155	162	167	172	177

Table 57.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age	Initial total basal area	Initial sawtimber/total basal area ratio									
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
A1	A2	BT1	BS2 (square feet/acre)										
40	60	20	20	29	38	43	47	49	51	53	54	55	56
		30	26	37	49	56	61	64	66	68	70	71	73
		40	31	45	59	67	73	76	79	82	84	85	87
		50	36	51	68	77	83	87	91	94	96	98	99
		60	40	57	75	86	92	97	101	104	107	109	111
		70	43	62	82	94	101	106	111	114	117	119	121
		80	47	67	89	101	109	115	119	123	126	128	130
		90	50	72	95	108	116	123	127	131	134	137	139
		100	53	76	100	114	123	130	135	139	142	145	147
		110	56	80	106	120	130	137	142	146	150	153	155
		120	58	84	111	126	136	143	149	153	157	160	162
		130	61	87	115	131	142	149	155	160	163	167	169
		140	63	91	120	136	147	155	161	166	170	173	176
		150	65	94	124	141	152	161	167	172	176	179	182
40	65	20	30	40	49	54	57	60	61	62	63	64	65
		30	38	51	63	69	73	76	78	79	81	82	83
		40	45	60	74	81	86	89	91	93	95	96	97
		50	50	67	83	91	97	100	103	105	107	108	109
		60	56	74	92	101	106	110	113	116	117	119	120
		70	60	80	99	109	115	119	122	125	127	129	130
		80	64	86	106	116	123	127	131	134	136	138	139
		90	68	91	112	123	130	135	139	142	144	146	147
		100	72	95	118	130	137	142	146	149	151	153	155
		110	75	100	123	135	143	149	153	156	158	160	162
		120	78	104	128	141	149	155	159	162	165	167	169
		130	81	108	133	146	155	160	165	168	171	173	175
		140	84	111	138	151	160	166	170	174	177	179	181
		150	86	115	142	156	165	171	176	179	182	185	187
40	70	20	41	52	61	65	68	70	71	72	73	73	74
		30	51	64	75	81	84	86	88	89	90	91	92
		40	59	74	87	93	97	100	102	103	105	106	106
		50	66	83	97	104	108	111	113	115	116	118	119
		60	72	90	106	113	118	121	124	125	127	128	129
		70	77	97	114	122	127	130	133	135	136	137	139
		80	82	103	120	129	134	138	141	143	144	146	147
		90	86	108	127	136	141	145	148	150	152	153	155
		100	90	113	133	142	148	152	155	157	159	161	162
		110	94	118	138	148	154	158	161	164	165	167	168
		120	97	122	143	153	160	164	167	170	171	173	174
		130	100	126	148	158	165	169	173	175	177	179	180
		140	103	130	152	163	170	174	178	180	182	184	186
		150	106	133	156	168	174	179	183	185	187	189	191

Table 57.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age	Initial total basal area	Initial sawtimber/total basal area ratio										
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
A1	A2	BT1	BS2 (square feet/acre)										
45	50	20	2	5	8	12	15	17	19	22	24	25	27
		30	4	7	12	17	21	25	28	31	34	37	39
		40	5	9	16	22	27	32	36	40	44	48	51
		50	6	11	19	27	33	39	44	49	54	58	62
		60	7	12	23	31	39	46	52	58	63	68	73
		70	8	14	26	36	45	52	60	66	72	78	83
		80	9	16	29	40	50	59	67	74	81	87	93
		90	9	18	32	44	55	65	74	82	90	97	103
		100	10	19	35	49	61	71	81	90	98	106	113
		110	11	21	38	53	66	78	88	98	107	115	123
		120	12	23	41	57	71	84	95	105	115	124	132
		130	13	24	44	61	76	89	102	113	123	133	142
		140	14	26	47	65	81	95	108	120	131	141	151
		150	15	27	50	69	86	101	115	127	139	150	160
45	55	20	5	9	15	19	23	26	28	30	32	34	35
		30	7	13	21	27	32	36	39	42	45	47	49
		40	9	16	26	34	40	45	49	53	56	59	62
		50	11	19	31	41	48	54	59	63	67	70	73
		60	13	22	36	47	55	62	68	73	77	81	85
		70	14	25	41	53	62	70	76	82	87	91	95
		80	16	28	45	58	69	77	85	91	96	101	105
		90	17	30	49	64	75	85	92	99	105	111	115
		100	19	33	54	69	81	91	100	107	114	120	125
		110	20	35	57	74	87	98	107	115	122	128	134
		120	22	37	61	79	93	105	114	123	130	137	143
		130	23	40	65	84	99	111	121	130	138	145	151
		140	24	42	69	88	104	117	128	138	146	153	160
		150	25	44	72	93	109	123	135	145	153	161	168
45	60	20	10	16	23	28	32	35	37	39	41	42	43
		30	13	21	32	38	43	47	50	53	55	57	58
		40	16	26	39	47	53	58	62	65	68	70	72
		50	19	31	46	55	63	68	73	76	79	82	84
		60	22	35	52	63	71	77	82	86	90	93	96
		70	24	39	58	70	79	86	91	96	100	103	106
		80	26	42	63	76	86	94	100	105	109	113	116
		90	28	46	68	83	93	102	108	114	118	122	126
		100	31	49	73	89	100	109	116	122	127	131	135
		110	32	52	78	94	106	116	123	130	135	139	143
		120	34	55	82	100	113	122	130	137	143	147	152
		130	36	58	86	105	118	129	137	144	150	155	159
		140	38	61	90	110	124	135	144	151	157	162	167
		150	40	63	94	115	129	141	150	158	164	170	174

ale 57.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

rtial ge (Years)	Final age	Initial total basal area	Initial sawtimber/total basal area ratio									
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
A1	A2	BT1	BS2 (square feet/acre)										
45	65	20	16	24	33	38	42	44	46	48	49	51	52
		30	21	32	43	50	55	58	61	63	65	67	68
		40	26	38	52	61	66	71	74	76	79	80	82
		50	30	44	60	70	77	81	85	88	91	93	94
		60	33	49	68	78	86	91	95	99	101	104	106
		70	36	54	74	86	94	100	105	108	111	114	116
		80	39	59	80	93	102	108	113	117	121	123	126
		90	42	63	86	100	109	116	121	126	129	132	135
		100	45	67	92	106	116	123	129	134	137	141	143
		110	47	71	97	112	123	130	136	141	145	149	151
		120	50	74	102	118	129	137	143	148	152	156	159
		130	52	78	106	123	135	143	150	155	159	163	166
		140	54	81	111	128	140	149	156	162	166	170	173
		150	56	84	115	133	146	155	162	168	172	176	180
45	70	20	24	34	43	48	51	54	56	57	58	59	60
		30	31	43	55	62	66	69	71	73	75	76	77
		40	37	51	66	73	78	82	85	87	89	90	91
		50	42	58	75	84	89	93	96	99	101	102	104
		60	47	65	83	92	99	103	107	109	112	113	115
		70	51	70	90	101	107	112	116	119	121	123	125
		80	54	75	97	108	115	121	125	128	130	133	134
		90	58	80	103	115	123	128	133	136	139	141	143
		100	61	85	109	121	130	136	140	144	146	149	151
		110	64	89	114	127	136	142	147	151	154	156	158
		120	67	93	119	133	142	149	153	157	161	163	165
		130	70	97	124	138	148	155	160	164	167	170	172
		140	72	100	128	143	153	160	166	170	173	176	178
		150	75	104	133	148	158	166	171	175	179	182	184
45	75	20	34	44	53	58	61	63	64	66	67	67	68
		30	42	55	67	73	77	79	81	83	84	85	86
		40	50	65	78	85	90	93	95	97	98	99	100
		50	56	73	88	96	101	104	107	109	110	111	113
		60	61	80	97	105	110	114	117	119	121	122	123
		70	66	86	104	113	119	123	126	128	130	132	133
		80	70	91	111	121	127	131	134	137	139	141	142
		90	74	97	117	128	134	139	142	145	147	149	150
		100	78	102	123	134	141	146	149	152	154	156	157
		110	81	106	129	140	147	152	156	159	161	163	164
		120	84	110	134	145	153	158	162	165	167	169	171
		130	87	114	138	151	158	164	168	171	173	175	177
		140	90	118	143	156	163	169	173	176	179	181	183
		150	93	121	147	160	168	174	178	182	184	186	188

Table 57.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age (Years)	Initial total basal area (Sq. ft.)	Initial sawtimber/total basal area ratio										
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.
A1	A2	BT1	BS2 (square feet/acre)										
50	55	20	2	4	8	11	14	16	19	21	23	25	26
		30	3	6	11	16	20	24	27	30	33	36	38
		40	4	8	15	21	26	31	35	39	43	46	50
		50	5	10	18	25	32	38	43	48	52	57	61
		60	6	12	21	30	37	44	50	56	62	67	71
		70	7	13	24	34	43	51	58	65	71	76	82
		80	8	15	28	38	48	57	65	73	80	86	92
		90	9	17	31	43	53	63	72	81	88	95	102
		100	10	18	33	47	59	69	79	88	97	105	112
		110	11	20	36	51	64	75	86	96	105	114	122
		120	11	21	39	55	69	81	93	103	113	123	131
		130	12	23	42	59	74	87	99	111	121	131	141
		140	13	24	45	63	78	93	106	118	129	140	150
		150	14	26	48	66	83	98	112	125	137	148	159
50	60	20	5	8	14	18	21	24	26	28	30	32	33
		30	6	11	19	25	30	34	37	40	42	45	47
		40	8	14	24	31	37	42	47	50	54	57	59
		50	10	17	29	38	45	51	56	60	64	68	71
		60	11	20	33	44	52	59	65	70	75	79	82
		70	13	23	38	49	59	66	73	79	84	89	93
		80	14	25	42	55	65	74	81	88	93	99	103
		90	16	27	46	60	71	81	89	96	102	108	113
		100	17	30	50	65	77	88	96	104	111	117	123
		110	18	32	53	70	83	94	104	112	119	126	132
		120	19	34	57	75	89	101	111	120	128	135	141
		130	21	36	61	79	94	107	118	127	135	143	150
		140	22	38	64	84	100	113	124	134	143	151	158
		150	23	40	67	88	105	119	131	141	151	159	166
50	65	20	8	14	21	26	29	32	34	36	38	39	41
		30	11	18	28	35	40	44	47	50	52	54	56
		40	14	23	35	43	49	54	58	61	64	67	69
		50	16	27	41	51	58	64	69	72	76	79	81
		60	19	31	47	58	66	73	78	83	86	90	92
		70	21	34	52	65	74	81	87	92	96	100	103
		80	23	38	58	71	81	89	96	101	106	110	113
		90	25	41	62	77	88	97	104	110	115	119	123
		100	27	44	67	83	95	104	111	118	123	128	132
		110	28	47	72	88	101	111	119	126	131	136	141
		120	30	50	76	94	107	117	126	133	139	144	149
		130	32	52	80	99	113	124	133	140	147	152	157
		140	33	55	84	104	118	130	139	147	154	160	165
		150	35	57	88	109	124	136	146	154	161	167	173

able 57.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age	Initial total basal area	Initial sawtimber/total basal area ratio										
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
A1	A2	BT1	BS2 (square feet/acre)										
50	70	20	13	21	29	34	38	41	43	44	46	47	48
		30	18	27	39	46	50	54	57	59	61	63	64
		40	22	33	47	55	61	66	69	72	74	76	78
		50	25	39	54	64	71	76	80	83	86	89	91
		60	28	43	61	72	80	86	90	94	97	100	102
		70	31	48	68	80	88	95	100	104	107	110	112
		80	34	52	74	87	96	103	108	113	116	119	122
		90	36	56	79	93	103	111	116	121	125	128	131
		100	39	60	84	99	110	118	124	129	133	137	140
		110	41	63	89	105	116	125	131	137	141	145	148
		120	43	67	94	111	123	131	138	144	149	153	156
		130	45	70	99	116	129	138	145	151	156	160	164
		140	47	73	103	121	134	144	151	158	163	167	171
		150	49	76	107	126	140	150	158	164	169	174	178
50	75	20	20	29	38	43	47	49	51	53	54	55	56
		30	26	37	49	56	61	64	66	68	70	71	73
		40	31	45	59	67	73	76	79	82	84	85	87
		50	36	51	68	77	83	87	91	94	96	98	99
		60	40	57	75	86	92	97	101	104	107	109	111
		70	43	62	82	94	101	106	111	114	117	119	121
		80	47	67	89	101	109	115	119	123	126	128	130
		90	50	72	95	108	116	123	127	131	134	137	139
		100	53	76	100	114	123	130	135	139	142	145	147
		110	56	80	106	120	130	137	142	146	150	153	155
		120	58	84	111	126	136	143	149	153	157	160	162
		130	61	87	115	131	142	149	155	160	163	167	169
		140	63	91	120	136	147	155	161	166	170	173	176
		150	65	94	124	141	152	161	167	172	176	179	182
50	80	20	28	38	47	52	55	57	59	60	62	62	63
		30	36	48	60	66	70	73	75	77	78	80	81
		40	42	57	71	78	83	86	89	91	93	94	95
		50	47	64	80	89	94	98	101	103	105	106	107
		60	52	71	88	98	104	108	111	113	115	117	118
		70	57	77	96	106	112	117	120	123	125	127	128
		80	61	82	103	113	120	125	129	132	134	136	138
		90	64	87	109	120	128	133	137	140	142	144	146
		100	68	92	115	127	134	140	144	147	150	152	154
		110	71	96	120	133	141	146	151	154	157	159	161
		120	74	100	125	138	147	153	157	161	163	166	168
		130	77	104	130	144	152	158	163	167	170	172	174
		140	80	107	134	149	158	164	169	173	176	178	180
		150	82	111	139	153	163	169	174	178	181	184	186

Table 57 --Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age	Initial total basal area	Initial sawtimber/total basal area ratio									
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
A1	A2	BT1	BS2 (square feet/acre)										
55	60	20	2	4	7	10	13	16	18	20	22	24	26
		30	3	6	11	15	19	23	26	29	32	35	38
		40	4	8	14	20	25	30	34	38	42	45	49
		50	5	9	17	24	31	36	42	47	51	56	60
		60	6	11	20	29	36	43	49	55	60	66	70
		70	7	13	23	33	41	49	56	63	69	75	81
		80	8	14	26	37	47	55	64	71	78	85	91
		90	8	16	29	41	52	62	71	79	87	94	101
		100	9	17	32	45	57	68	78	87	95	103	111
		110	10	19	35	49	62	74	84	94	104	112	121
		120	11	20	38	53	67	79	91	102	112	121	130
		130	12	22	40	57	72	85	98	109	120	130	140
		140	12	23	43	61	76	91	104	116	128	139	149
		150	13	25	46	64	81	96	111	124	136	147	158
55	65	20	4	7	12	16	20	22	25	27	29	31	32
		30	6	10	17	23	28	32	35	38	41	43	45
		40	7	13	22	29	35	40	45	48	52	55	58
		50	9	16	27	35	42	48	54	58	62	66	69
		60	10	18	31	41	49	56	62	68	72	77	80
		70	12	21	35	46	56	64	70	76	82	87	91
		80	13	23	39	52	62	71	78	85	91	96	101
		90	14	25	43	57	68	78	86	93	100	106	111
		100	15	27	47	62	74	84	94	101	109	115	121
		110	17	30	50	66	80	91	101	109	117	124	130
		120	18	32	54	71	85	97	108	117	125	133	139
		130	19	34	57	76	91	104	115	124	133	141	148
		140	20	36	60	80	96	110	121	132	141	149	157
		150	21	38	64	84	101	116	128	139	149	157	165
55	70	20	7	12	19	23	27	30	32	34	36	37	39
		30	10	16	26	32	37	41	44	47	49	51	53
		40	12	20	32	40	46	51	55	59	61	64	66
		50	14	24	38	47	55	60	65	69	73	76	78
		60	16	28	43	54	62	69	75	79	83	87	90
		70	18	31	48	61	70	77	83	89	93	97	100
		80	20	34	53	67	77	85	92	98	102	107	111
		90	22	37	58	73	84	93	100	106	111	116	120
		100	24	40	62	78	90	100	108	114	120	125	129
		110	25	43	67	83	96	107	115	122	128	134	138
		120	27	45	71	89	102	113	122	130	136	142	147
		130	28	48	75	94	108	120	129	137	144	150	155
		140	30	50	79	98	114	126	136	144	151	158	163
		150	31	53	82	103	119	132	142	151	159	165	171

Table 57.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age	Initial total basal area	Initial sawtimber/total basal area ratio										
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
A1	A2	BT1	BS2 (square feet/acre)										
55	75	20	11	18	26	31	35	37	40	41	43	44	45
		30	15	24	35	42	47	50	53	56	58	60	61
		40	19	29	43	51	57	62	65	68	71	73	75
		50	22	34	50	59	66	72	76	80	82	85	87
		60	25	39	56	67	75	81	86	90	93	96	99
		70	27	43	62	74	83	90	95	100	103	106	109
		80	30	47	68	81	91	98	104	109	113	116	119
		90	32	50	73	88	98	106	112	117	121	125	128
		100	34	54	78	94	105	113	120	125	130	134	137
		110	36	57	83	99	111	120	127	133	138	142	146
		120	38	60	88	105	117	127	134	140	145	150	154
		130	40	63	92	110	123	133	141	147	153	157	161
		140	42	66	96	115	129	139	147	154	160	165	169
		150	44	69	100	120	134	145	154	161	167	172	176
55	80	20	17	25	34	39	43	45	47	49	50	51	52
		30	22	33	44	51	56	59	62	64	66	67	69
		40	27	39	54	62	68	72	75	77	80	81	83
		50	31	45	62	71	78	82	86	89	92	94	95
		60	34	51	69	80	87	92	96	100	102	105	107
		70	38	56	76	87	95	101	106	109	112	115	117
		80	41	60	82	95	103	110	114	118	122	124	127
		90	44	65	88	101	111	117	123	127	130	133	136
		100	46	69	93	108	117	125	130	135	138	141	144
		110	49	72	98	114	124	132	137	142	146	149	152
		120	51	76	103	119	130	138	144	149	153	157	160
		130	54	79	108	125	136	144	151	156	160	164	167
		140	56	83	112	130	142	150	157	162	167	171	174
		150	58	86	117	135	147	156	163	168	173	177	180
60	65	20	2	4	7	10	13	15	17	20	22	24	25
		30	3	6	10	15	19	22	25	29	32	34	37
		40	4	7	14	19	24	29	33	37	41	45	48
		50	5	9	17	23	30	35	41	46	50	55	59
		60	6	11	20	28	35	42	48	54	59	65	70
		70	6	12	23	32	40	48	55	62	68	74	80
		80	7	14	25	36	45	54	62	70	77	84	90
		90	8	15	28	40	50	60	69	78	86	93	100
		100	9	17	31	44	55	66	76	85	94	102	110
		110	10	18	34	48	60	72	83	93	102	111	120
		120	10	20	36	51	65	78	89	100	111	120	129
		130	11	21	39	55	70	83	96	108	119	129	139
		140	12	22	42	59	75	89	103	115	127	138	148
		150	13	24	44	63	79	95	109	122	135	146	158

Table 57.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age	Initial total basal area	Initial sawtimber/total basal area ratio										
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
A1	A2	BT1	BS2 (square feet/acre)										
60	70	20	4	7	11	15	19	21	24	26	28	29	31
		30	5	9	16	22	26	30	34	37	39	42	44
		40	7	12	21	28	34	39	43	47	50	53	56
		50	8	15	25	33	40	46	52	56	60	64	68
		60	9	17	29	39	47	54	60	66	70	75	79
		70	11	19	33	44	53	61	68	74	80	85	89
		80	12	21	37	49	59	68	76	83	89	95	100
		90	13	24	40	54	65	75	84	91	98	104	110
		100	14	26	44	59	71	82	91	99	107	113	119
		110	15	28	48	63	77	88	98	107	115	122	129
		120	16	30	51	68	82	94	105	115	123	131	138
		130	17	32	54	72	88	101	112	122	131	139	147
		140	18	33	57	77	93	107	119	129	139	148	155
		150	20	35	61	81	98	113	125	137	147	156	164
60	75	20	6	11	17	22	25	28	30	32	34	36	37
		30	9	15	23	30	35	39	42	45	47	49	51
		40	11	18	29	37	43	48	53	56	59	62	64
		50	13	22	35	44	52	57	62	67	70	73	76
		60	15	25	40	51	59	66	72	76	81	84	87
		70	17	28	45	57	66	74	80	86	90	94	98
		80	18	31	50	63	73	82	89	95	100	104	108
		90	20	34	54	69	80	89	97	103	109	114	118
		100	21	37	58	74	86	96	104	111	117	123	127
		110	23	39	62	79	92	103	112	119	126	131	136
		120	24	42	66	84	98	109	119	127	134	140	145
		130	26	44	70	89	104	116	126	134	141	148	154
		140	27	46	74	94	109	122	132	141	149	156	162
		150	29	49	78	99	115	128	139	148	156	163	170
60	80	20	10	16	23	28	32	35	37	39	41	42	43
		30	13	21	32	38	43	47	50	53	55	57	58
		40	16	26	39	47	53	58	62	65	68	70	72
		50	19	31	46	55	63	68	73	76	79	82	84
		60	22	35	52	63	71	77	82	86	90	93	96
		70	24	39	58	70	79	86	91	96	100	103	106
		80	26	42	63	76	86	94	100	105	109	113	116
		90	28	46	68	83	93	102	108	114	118	122	126
		100	31	49	73	89	100	109	116	122	127	131	135
		110	32	52	78	94	106	116	123	130	135	139	143
		120	34	55	82	100	113	122	130	137	143	147	152
		130	36	58	86	105	118	129	137	144	150	155	159
		140	38	61	90	110	124	135	144	151	157	162	167
		150	40	63	94	115	129	141	150	158	164	170	174

Table 57.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age	Initial total basal area	Initial sawtimber/total basal area ratio										
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
A1	A2	BT1	BS2 (square feet/acre)										
65	70	20	2	4	7	10	12	15	17	19	21	23	25
		30	3	5	10	14	18	22	25	28	31	34	36
		40	4	7	13	19	24	28	32	37	40	44	47
		50	4	9	16	23	29	35	40	45	50	54	58
		60	5	10	19	27	34	41	47	53	59	64	69
		70	6	12	22	31	39	47	54	61	67	73	79
		80	7	13	25	35	44	53	61	69	76	83	89
		90	8	15	27	39	49	59	68	77	85	92	99
		100	8	16	30	43	54	65	75	84	93	101	109
		110	9	18	33	46	59	71	82	92	101	110	119
		120	10	19	35	50	64	76	88	99	110	119	129
		130	11	20	38	54	69	82	95	107	118	128	138
		140	11	22	41	58	73	88	101	114	126	137	148
		150	12	23	43	61	78	93	108	121	134	146	157
65	75	20	3	6	11	14	18	20	23	25	27	29	30
		30	5	9	15	21	25	29	32	35	38	41	43
		40	6	11	20	26	32	37	41	45	49	52	55
		50	7	14	24	32	39	45	50	55	59	63	66
		60	9	16	28	37	45	52	58	64	69	73	77
		70	10	18	31	42	51	59	66	72	78	83	88
		80	11	20	35	47	57	66	74	81	87	93	98
		90	12	22	39	52	63	73	81	89	96	102	108
		100	13	24	42	56	69	79	89	97	105	112	118
		110	14	26	45	61	74	86	96	105	113	121	127
		120	15	28	49	65	80	92	103	113	121	129	137
		130	16	30	52	70	85	98	110	120	129	138	146
		140	17	32	55	74	90	104	116	127	137	146	154
		150	18	33	58	78	95	110	123	135	145	154	163
65	80	20	6	10	16	20	23	26	29	31	33	34	36
		30	8	13	22	28	33	37	40	43	45	48	50
		40	10	17	27	35	41	46	50	54	57	60	62
		50	12	20	33	42	49	55	60	64	68	71	74
		60	13	23	37	48	56	63	69	74	78	82	85
		70	15	26	42	54	63	71	78	83	88	92	96
		80	17	29	47	60	70	79	86	92	97	102	106
		90	18	31	51	65	77	86	94	100	106	112	116
		100	20	34	55	71	83	93	101	109	115	121	126
		110	21	36	59	76	89	100	109	116	123	129	135
		120	22	39	63	81	95	106	116	124	131	138	143
		130	24	41	67	85	100	112	123	132	139	146	152
		140	25	43	70	90	106	119	129	139	147	154	160
		150	26	45	74	95	111	125	136	146	154	162	168

Table 57.--Projected sawtimber basal area (BS2) by initial age, final age, and initial total basal area for natural, even-aged stands of longleaf pine in the East Gulf.

Initial age (Years)	Final age (Years)	Initial total basal area (Sq. ft.)	Initial sawtimber/total basal area ratio										
			0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
A1	A2	BT1	BS2 (square feet/acre)										
70	75	20	2	4	7	9	12	14	17	19	21	23	25
		30	3	5	10	14	18	21	24	27	30	33	36
		40	4	7	13	18	23	28	32	36	40	43	47
		50	4	8	16	22	28	34	39	44	49	53	58
		60	5	10	18	26	33	40	46	52	58	63	68
		70	6	11	21	30	38	46	53	60	67	73	79
		80	7	13	24	34	43	52	60	68	75	82	89
		90	7	14	27	38	48	58	67	76	84	91	99
		100	8	16	29	42	53	64	74	83	92	101	109
		110	9	17	32	45	58	70	81	91	100	110	118
		120	10	18	35	49	63	75	87	98	109	119	128
		130	10	20	37	53	67	81	94	106	117	128	138
		140	11	21	40	56	72	86	100	113	125	136	147
		150	12	22	42	60	77	92	106	120	133	145	157
70	80	20	3	6	10	14	17	19	22	24	26	28	29
		30	4	8	14	20	24	28	31	34	37	40	43
		40	6	11	19	25	31	36	40	44	48	51	54
		50	7	13	22	30	37	43	49	53	58	62	65
		60	8	15	26	36	44	51	57	62	67	72	76
		70	9	17	30	40	50	58	65	71	77	82	87
		80	10	19	33	45	55	64	72	79	86	92	97
		90	11	21	37	50	61	71	80	87	95	101	107
		100	12	23	40	54	67	77	87	95	103	110	117
		110	13	25	43	59	72	84	94	103	112	119	126
		120	14	27	47	63	77	90	101	111	120	128	135
		130	15	28	50	68	83	96	108	118	128	137	145
		140	16	30	53	72	88	102	114	126	136	145	154
		150	17	32	56	76	93	108	121	133	143	153	162
75	80	20	2	3	6	9	12	14	16	18	20	22	24
		30	3	5	9	13	17	21	24	27	30	33	35
		40	3	7	12	18	22	27	31	35	39	43	46
		50	4	8	15	22	28	33	39	44	48	53	57
		60	5	9	18	26	33	39	46	52	57	63	68
		70	6	11	21	29	38	45	53	59	66	72	78
		80	6	12	23	33	43	51	59	67	75	82	88
		90	7	14	26	37	47	57	66	75	83	91	98
		100	8	15	29	41	52	63	73	82	91	100	108
		110	9	17	31	45	57	69	80	90	100	109	118
		120	9	18	34	48	62	74	86	97	108	118	128
		130	10	19	36	52	66	80	93	105	116	127	137
		140	11	21	39	55	71	85	99	112	124	136	147
		150	11	22	41	59	76	91	105	119	132	144	156

ble 58.--Sawtimber stand volume, cubic feet, i.b., (VIS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age ears)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	VIS (cubic feet,i.b.,/acre)				
20	5	39	45	53	62	73
	10	77	90	106	124	145
	15	116	135	159	185	217
	20	154	180	211	247	289
	25	193	225	264	308	361
	30	231	270	316	370	433
	35	269	315	369	431	504
	40	308	360	421	493	576
25	5	52	61	71	83	97
	10	104	121	142	166	194
	15	155	182	213	249	291
	20	207	242	283	331	387
	25	258	302	354	414	484
	30	310	362	424	496	580
	35	361	423	494	578	677
	40	413	483	565	661	773
	45	464	543	635	743	869
	50	515	603	705	825	965
	55	567	663	776	907	1061
	60	618	723	846	989	1157
	65	669	783	916	1071	1253
	70	721	843	986	1154	1349
	75	772	903	1056	1236	1445
	80	823	963	1126	1318	1541
30	5	63	74	87	101	118
	10	126	148	173	202	236
	15	189	221	259	302	354
	20	252	294	344	403	471
	25	314	368	430	503	588
	30	377	441	516	603	706
	35	439	514	601	703	823
	40	502	587	687	803	940
	45	564	660	772	903	1057
	50	627	733	858	1003	1174
	55	689	806	943	1103	1291
	60	752	879	1029	1203	1408
	65	814	952	1114	1303	1524
	70	876	1025	1199	1403	1641
	75	939	1098	1285	1503	1758
	80	1001	1171	1370	1603	1875
	85	1063	1244	1455	1702	1991

Table 58.--Sawtimber stand volume, cubic feet, i.b., (VIS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (Years)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	VIS (cubic feet,i.b.,/acre)				
30	90	1126	1317	1540	1802	2108
	95	1188	1390	1626	1902	2225
	100	1250	1463	1711	2001	2341
	105	1313	1535	1796	2101	2458
	110	1375	1608	1881	2201	2574
	115	1437	1681	1966	2300	2691
	120	1499	1754	2052	2400	2808
35	5	73	85	100	116	136
	10	145	170	199	232	272
	15	217	254	297	348	407
	20	289	338	396	463	542
	25	361	423	495	579	677
	30	433	507	593	694	812
	35	505	591	691	809	946
	40	577	675	790	924	1081
	45	649	759	888	1039	1215
	50	721	843	986	1154	1350
	55	793	927	1085	1269	1484
	60	864	1011	1183	1384	1619
	65	936	1095	1281	1499	1753
	70	1008	1179	1379	1613	1887
	75	1080	1263	1477	1728	2022
	80	1151	1347	1575	1843	2156
	85	1223	1431	1673	1958	2290
	90	1295	1514	1772	2072	2424
	95	1366	1598	1870	2187	2558
	100	1438	1682	1968	2302	2693
	105	1509	1766	2066	2416	2827
	110	1581	1849	2164	2531	2961
	115	1653	1933	2261	2645	3095
	120	1724	2017	2359	2760	3229
	125	1796	2101	2457	2875	3363
	130	1867	2184	2555	2989	3497
	135	1939	2268	2653	3104	3631
	140	2010	2352	2751	3218	3765
	145	2082	2435	2849	3333	3899
	150	2153	2519	2947	3447	4032
	155	2225	2603	3045	3562	4166
	160	2296	2686	3142	3676	4300
40	10	161	188	220	258	302
	15	241	282	330	386	452
	20	321	376	440	514	602
	25	401	469	549	642	752
	30	481	563	659	770	901

able 58.--Sawtimber stand volume, cubic feet, i.b., (VIS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age	Sawtimber basal area	Site index (Ft.)				
Years)	(Sq. ft.)	50	60	70	80	90
A	BS	VIS (cubic feet,i.b.,/acre)				
40	35	561	656	768	898	1051
	40	641	750	877	1026	1200
	45	721	843	986	1154	1350
	50	800	936	1095	1281	1499
	55	880	1030	1205	1409	1648
	60	960	1123	1314	1537	1798
	65	1040	1216	1423	1664	1947
	70	1119	1309	1532	1792	2096
	75	1199	1402	1641	1919	2245
	80	1278	1496	1750	2047	2394
	85	1358	1589	1858	2174	2543
	90	1438	1682	1967	2301	2692
	95	1517	1775	2076	2429	2841
	100	1597	1868	2185	2556	2990
	105	1676	1961	2294	2683	3139
	110	1756	2054	2403	2811	3288
	115	1835	2147	2511	2938	3437
	120	1915	2240	2620	3065	3586
	125	1994	2333	2729	3192	3734
	130	2074	2426	2838	3319	3883
	135	2153	2519	2946	3447	4032
	140	2232	2612	3055	3574	4181
	145	2312	2704	3164	3701	4329
	150	2391	2797	3272	3828	4478
	155	2471	2890	3381	3955	4627
	160	2550	2983	3490	4082	4775
	165	2629	3076	3598	4209	4924
45	10	175	204	239	280	327
	15	262	306	358	419	490
	20	349	408	477	558	653
	25	435	509	596	697	815
	30	522	611	714	836	978
	35	609	712	833	975	1140
	40	695	813	952	1113	1302
	45	782	915	1070	1252	1464
	50	868	1016	1188	1390	1626
	55	955	1117	1307	1529	1788
	60	1041	1218	1425	1667	1950
	65	1128	1319	1543	1806	2112
	70	1214	1421	1662	1944	2274
	75	1301	1522	1780	2082	2436
	80	1387	1623	1898	2220	2598
	85	1473	1724	2016	2359	2759
	90	1560	1825	2134	2497	2921
	95	1646	1926	2253	2635	3082

Table 58.--Sawtimber stand volume, cubic feet, i.b., (VIS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (Years)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	VIS (cubic feet,i.b.,/acre)				
45	100	1732	2027	2371	2773	3244
	105	1819	2127	2489	2911	3406
	110	1905	2228	2607	3049	3567
	115	1991	2329	2725	3187	3729
	120	2077	2430	2843	3325	3890
	125	2164	2531	2961	3463	4052
	130	2250	2632	3079	3601	4213
	135	2336	2733	3197	3739	4374
	140	2422	2833	3315	3877	4536
	145	2508	2934	3432	4015	4697
	150	2594	3035	3550	4153	4859
	155	2681	3136	3668	4291	5020
	160	2767	3237	3786	4429	5181
	165	2853	3337	3904	4567	5342
	170	2939	3438	4022	4705	5504
50	10	187	218	255	299	349
	15	279	327	382	447	523
	20	372	435	509	596	697
	25	465	544	636	744	870
	30	557	652	763	892	1044
	35	650	760	889	1040	1217
	40	742	868	1016	1188	1390
	45	835	976	1142	1336	1563
	50	927	1084	1269	1484	1736
	55	1019	1192	1395	1632	1909
	60	1112	1300	1521	1780	2082
	65	1204	1408	1647	1927	2255
	70	1296	1516	1774	2075	2427
	75	1388	1624	1900	2223	2600
	80	1481	1732	2026	2370	2773
	85	1573	1840	2152	2518	2945
	90	1665	1948	2278	2665	3118
	95	1757	2055	2404	2813	3290
	100	1849	2163	2530	2960	3463
	105	1941	2271	2656	3108	3635
	110	2033	2379	2782	3255	3808
	115	2125	2486	2908	3402	3980
	120	2217	2594	3034	3550	4152
	125	2309	2702	3160	3697	4325
	130	2401	2809	3286	3844	4497
	135	2493	2917	3412	3991	4669
	140	2585	3024	3538	4139	4842
	145	2677	3132	3664	4286	5014

ble 58.--Sawtimber stand volume, cubic feet, i.b., (VIS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age ears)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	VIS (cubic feet,i.b.,/acre)				
50	150	2769	3240	3790	4433	5186
	155	2861	3347	3915	4580	5358
	160	2953	3455	4041	4728	5530
	165	3045	3562	4167	4875	5702
	170	3137	3670	4293	5022	5875
	175	3229	3777	4419	5169	6047
55	15	295	345	403	472	552
	20	393	459	537	628	735
	25	490	573	671	785	918
	30	588	688	804	941	1101
	35	685	802	938	1097	1284
	40	783	916	1071	1253	1466
	45	880	1030	1205	1409	1649
	50	978	1144	1338	1565	1831
	55	1075	1258	1471	1721	2014
	60	1173	1372	1605	1877	2196
	65	1270	1486	1738	2033	2378
	70	1367	1599	1871	2189	2560
	75	1464	1713	2004	2344	2742
	80	1562	1827	2137	2500	2925
	85	1659	1941	2270	2656	3107
	90	1756	2054	2403	2811	3289
	95	1853	2168	2536	2967	3471
	100	1950	2282	2669	3122	3653
	105	2048	2395	2802	3278	3834
	110	2145	2509	2935	3433	4016
	115	2242	2623	3068	3589	4198
	120	2339	2736	3201	3744	4380
	125	2436	2850	3334	3900	4562
	130	2533	2963	3466	4055	4744
	135	2630	3077	3599	4210	4925
	140	2727	3190	3732	4366	5107
	145	2824	3304	3865	4521	5289
	150	2921	3417	3997	4676	5470
	155	3018	3531	4130	4831	5652
	160	3115	3644	4263	4987	5833
	165	3212	3757	4396	5142	6015
	170	3309	3871	4528	5297	6197
	175	3406	3984	4661	5452	6378
	180	3503	4098	4794	5607	6560
60	15	308	360	422	493	577
	20	410	480	562	657	768
	25	513	600	701	820	960
	30	615	719	841	984	1151
	35	717	838	981	1147	1342

Table 58.--Sawtimber stand volume, cubic feet, i.b., (VIS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (Years)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	VIS (cubic feet,i.b.,/acre)				
60	40	819	958	1120	1310	1533
	45	920	1077	1260	1473	1724
	50	1022	1196	1399	1637	1914
	55	1124	1315	1538	1800	2105
	60	1226	1434	1678	1962	2296
	65	1328	1553	1817	2125	2486
	70	1429	1672	1956	2288	2677
	75	1531	1791	2095	2451	2867
	80	1633	1910	2234	2614	3058
	85	1734	2029	2373	2776	3248
	90	1836	2148	2512	2939	3438
	95	1938	2267	2651	3102	3628
	100	2039	2385	2790	3264	3819
	105	2141	2504	2929	3427	4009
	110	2242	2623	3068	3589	4199
	115	2344	2742	3207	3752	4389
	120	2445	2861	3346	3914	4579
	125	2547	2979	3485	4077	4769
	130	2648	3098	3624	4239	4959
	135	2750	3217	3763	4402	5149
	140	2851	3335	3902	4564	5339
	145	2953	3454	4040	4727	5529
	150	3054	3573	4179	4889	5719
	155	3155	3691	4318	5051	5909
	160	3257	3810	4457	5213	6099
	165	3358	3928	4595	5376	6289
	170	3459	4047	4734	5538	6478
	175	3561	4165	4873	5700	6668
	180	3662	4284	5012	5863	6858
	185	3764	4403	5150	6025	7048
65	15	320	374	438	512	599
	20	426	498	583	682	798
	25	532	623	728	852	997
	30	638	747	873	1022	1195
	35	744	870	1018	1191	1393
	40	850	994	1163	1361	1592
	45	956	1118	1308	1530	1790
	50	1062	1242	1453	1699	1988
	55	1167	1365	1597	1869	2186
	60	1273	1489	1742	2038	2384
	65	1379	1613	1887	2207	2582
	70	1484	1736	2031	2376	2779
	75	1590	1860	2176	2545	2977
	80	1695	1983	2320	2714	3175
	85	1801	2107	2464	2883	3372

ble 58.--Sawtimber stand volume, cubic feet, i.b., (VIS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age ears)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	VIS (cubic feet,i.b.,/acre)				
65	90	1906	2230	2609	3052	3570
	95	2012	2354	2753	3221	3768
	100	2117	2477	2898	3390	3965
	105	2223	2600	3042	3558	4163
	110	2328	2724	3186	3727	4360
	115	2434	2847	3330	3896	4557
	120	2539	2970	3475	4065	4755
	125	2644	3093	3619	4233	4952
	130	2750	3217	3763	4402	5149
	135	2855	3340	3907	4571	5347
	140	2960	3463	4051	4739	5544
	145	3066	3586	4195	4908	5741
	150	3171	3710	4339	5076	5938
	155	3276	3833	4484	5245	6136
	160	3382	3956	4628	5413	6333
	165	3487	4079	4772	5582	6530
	170	3592	4202	4916	5750	6727
	175	3697	4325	5060	5919	6924
	180	3803	4448	5204	6087	7121
	185	3908	4571	5348	6256	7318
	190	4013	4694	5492	6424	7515
70	20	440	515	602	704	824
	25	550	643	752	880	1029
	30	659	771	902	1055	1234
	35	768	899	1052	1230	1439
	40	878	1027	1201	1405	1644
	45	987	1155	1351	1580	1848
	50	1096	1282	1500	1755	2053
	55	1206	1410	1650	1930	2257
	60	1315	1538	1799	2105	2462
	65	1424	1666	1948	2279	2666
	70	1533	1793	2098	2454	2871
	75	1642	1921	2247	2628	3075
	80	1751	2048	2396	2803	3279
	85	1860	2176	2545	2977	3483
	90	1969	2303	2694	3152	3687
	95	2078	2431	2843	3326	3891
	100	2187	2558	2992	3501	4095
	105	2296	2685	3142	3675	4299
	110	2405	2813	3291	3849	4503
	115	2513	2940	3440	4024	4707
	120	2622	3068	3588	4198	4911
	125	2731	3195	3737	4372	5114
	130	2840	3322	3886	4546	5318
	135	2949	3449	4035	4720	5522

Table 58.--Sawtimber stand volume, cubic feet, i.b., (VIS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (Years)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	VIS (cubic feet,i.b.,/acre)				
70	140	3058	3577	4184	4895	5726
	145	3166	3704	4333	5069	5929
	150	3275	3831	4482	5243	6133
	155	3384	3958	4631	5417	6337
	160	3492	4086	4779	5591	6540
	165	3601	4213	4928	5765	6744
	170	3710	4340	5077	5939	6947
	175	3819	4467	5226	6113	7151
	180	3927	4594	5374	6287	7354
	185	4036	4721	5523	6461	7558
	190	4145	4848	5672	6635	7761
	195	4253	4975	5820	6809	7965
	200	4362	5103	5969	6983	8168
75	20	453	529	619	724	847
	25	565	661	773	905	1058
	30	678	793	927	1085	1269
	35	790	924	1081	1265	1480
	40	903	1056	1235	1445	1690
	45	1015	1187	1389	1625	1901
	50	1127	1319	1543	1805	2111
	55	1240	1450	1696	1985	2321
	60	1352	1581	1850	2164	2532
	65	1464	1713	2004	2344	2742
	70	1576	1844	2157	2523	2952
	75	1688	1975	2311	2703	3162
	80	1801	2106	2464	2882	3372
	85	1913	2237	2617	3062	3582
	90	2025	2369	2771	3241	3792
	95	2137	2500	2924	3421	4001
	100	2249	2631	3077	3600	4211
	105	2361	2762	3231	3779	4421
	110	2473	2893	3384	3958	4631
	115	2585	3024	3537	4138	4840
	120	2697	3155	3690	4317	5050
	125	2809	3285	3843	4496	5259
	130	2920	3416	3996	4675	5469
	135	3032	3547	4150	4854	5678
	140	3144	3678	4303	5033	5888
	145	3256	3809	4456	5212	6097
	150	3368	3940	4609	5391	6307
	155	3480	4071	4762	5570	6516
	160	3591	4201	4915	5749	6726
	165	3703	4332	5068	5928	6935
	170	3815	4463	5221	6107	7144
	175	3927	4594	5374	6286	7354

le 58.--Sawtimber stand volume, cubic feet, i.b., (VIS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

ge ars)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	VIS (cubic feet,i.b.,/acre)				
75	180	4039	4724	5527	6465	7563
	185	4150	4855	5680	6644	7772
	190	4262	4986	5832	6823	7981
	195	4374	5116	5985	7002	8191
	200	4486	5247	6138	7181	8400
80	20	464	543	635	742	868
	25	579	678	793	927	1085
	30	695	812	950	1112	1301
	35	810	947	1108	1296	1517
	40	925	1082	1266	1481	1732
	45	1040	1217	1423	1665	1948
	50	1155	1351	1581	1849	2164
	55	1270	1486	1738	2034	2379
	60	1385	1621	1896	2218	2594
	65	1500	1755	2053	2402	2810
	70	1615	1890	2211	2586	3025
	75	1730	2024	2368	2770	3240
	80	1845	2158	2525	2954	3455
	85	1960	2293	2682	3138	3670
	90	2075	2427	2839	3321	3885
	95	2190	2561	2996	3505	4100
	100	2304	2696	3154	3689	4315
	105	2419	2830	3311	3873	4530
	110	2534	2964	3468	4056	4745
	115	2649	3098	3625	4240	4960
	120	2763	3233	3782	4424	5175
	125	2878	3367	3939	4607	5390
	130	2993	3501	4095	4791	5604
	135	3107	3635	4252	4974	5819
	140	3222	3769	4409	5158	6034
	145	3337	3903	4566	5341	6248
	150	3451	4037	4723	5525	6463
	155	3566	4171	4880	5708	6678
	160	3680	4305	5036	5892	6892
	165	3795	4439	5193	6075	7107
	170	3910	4573	5350	6258	7321
	175	4024	4707	5507	6442	7536
	180	4139	4841	5663	6625	7750
	185	4253	4975	5820	6808	7965
	190	4368	5109	5977	6992	8179
	195	4482	5243	6134	7175	8393
	200	4597	5377	6290	7358	8608

Table 59 --Sawtimber stand volume, cubic feet, o.b., (VOS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (Years)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	VOS (cubic feet,o.b.,/acre)				
20	5	56	64	74	86	99
	10	111	129	149	172	199
	15	167	193	223	258	298
	20	223	258	298	345	398
	25	279	323	373	431	498
	30	335	387	448	517	598
	35	391	452	522	604	698
	40	447	517	597	690	797
25	5	72	83	96	111	128
	10	144	166	192	222	256
	15	216	249	288	333	385
	20	288	333	384	444	513
	25	360	416	481	556	642
	30	432	499	577	667	771
	35	504	583	673	778	900
	40	576	666	770	890	1028
	45	649	750	866	1001	1157
	50	721	833	963	1113	1286
	55	793	916	1059	1224	1415
	60	865	1000	1156	1336	1544
	65	937	1083	1252	1447	1673
	70	1010	1167	1349	1559	1802
	75	1082	1250	1445	1670	1930
	80	1154	1334	1542	1782	2059
30	5	85	98	114	131	152
	10	170	197	227	263	304
	15	256	295	341	395	456
	20	341	394	455	526	608
	25	426	493	570	658	761
	30	512	592	684	790	913
	35	597	690	798	922	1066
	40	683	789	912	1054	1218
	45	768	888	1026	1186	1371
	50	854	987	1141	1318	1524
	55	939	1086	1255	1450	1676
	60	1025	1185	1369	1582	1829
	65	1111	1284	1484	1715	1982
	70	1196	1383	1598	1847	2134
	75	1282	1482	1712	1979	2287
	80	1368	1580	1827	2111	2440
	85	1453	1679	1941	2243	2593

Table 59.--Sawtimber stand volume, cubic feet, o.b., (VOS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (Years)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	VOS (cubic feet,o.b.,/acre)				
30	90	1539	1778	2055	2376	2746
	95	1624	1877	2170	2508	2898
	100	1710	1976	2284	2640	3051
	105	1796	2075	2399	2772	3204
	110	1881	2174	2513	2905	3357
	115	1967	2274	2628	3037	3510
	120	2053	2373	2742	3169	3663
35	5	96	111	128	148	171
	10	192	222	257	297	343
	15	289	333	385	445	515
	20	385	445	514	594	687
	25	481	556	643	743	859
	30	578	668	772	892	1031
	35	674	779	901	1041	1203
	40	771	891	1030	1190	1375
	45	867	1002	1158	1339	1547
	50	964	1114	1287	1488	1720
	55	1060	1226	1416	1637	1892
	60	1157	1337	1546	1786	2064
	65	1254	1449	1675	1935	2237
	70	1350	1561	1804	2085	2409
	75	1447	1672	1933	2234	2582
	80	1544	1784	2062	2383	2754
	85	1640	1896	2191	2532	2926
	90	1737	2007	2320	2681	3099
	95	1834	2119	2449	2831	3271
	100	1930	2231	2578	2980	3444
	105	2027	2343	2708	3129	3617
	110	2124	2454	2837	3278	3789
	115	2220	2566	2966	3428	3962
	120	2317	2678	3095	3577	4134
	125	2414	2790	3224	3726	4307
	130	2511	2902	3354	3876	4479
	135	2607	3013	3483	4025	4652
	140	2704	3125	3612	4175	4825
	145	2801	3237	3741	4324	4997
	150	2898	3349	3870	4473	5170
	155	2994	3461	4000	4623	5343
	160	3091	3573	4129	4772	5515
40	10	210	243	281	325	375
	15	316	365	422	488	564
	20	421	487	563	651	752
	25	527	609	704	814	940
	30	633	731	845	977	1129

Table 59.--Sawtimber stand volume, cubic feet, o.b., (VOS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (Years)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	VOS (cubic feet,o.b.,/acre)				
40	35	738	853	986	1140	1317
	40	844	976	1127	1303	1506
	45	950	1098	1269	1466	1695
	50	1056	1220	1410	1629	1883
	55	1161	1342	1551	1793	2072
	60	1267	1464	1692	1956	2261
	65	1373	1587	1834	2119	2449
	70	1479	1709	1975	2283	2638
	75	1584	1831	2116	2446	2827
	80	1690	1954	2258	2609	3016
	85	1796	2076	2399	2773	3205
	90	1902	2198	2541	2936	3394
	95	2008	2321	2682	3100	3582
	100	2114	2443	2823	3263	3771
	105	2220	2565	2965	3427	3960
	110	2326	2688	3106	3590	4149
	115	2432	2810	3248	3754	4338
	120	2537	2933	3389	3917	4527
	125	2643	3055	3531	4081	4716
	130	2749	3177	3672	4244	4905
	135	2855	3300	3814	4408	5094
	140	2961	3422	3955	4571	5283
	145	3067	3545	4097	4735	5472
	150	3173	3667	4238	4899	5661
	155	3279	3790	4380	5062	5851
	160	3385	3912	4522	5226	6040
	165	3491	4035	4663	5389	6229
45	10	226	261	302	349	403
	15	339	392	453	523	605
	20	452	523	604	698	807
	25	566	654	756	873	1009
	30	679	785	907	1048	1211
	35	792	916	1058	1223	1414
	40	906	1047	1210	1398	1616
	45	1019	1178	1361	1574	1819
	50	1133	1309	1513	1749	2021
	55	1246	1440	1665	1924	2224
	60	1360	1572	1816	2099	2426
	65	1473	1703	1968	2274	2629
	70	1587	1834	2120	2450	2831
	75	1700	1965	2271	2625	3034
	80	1814	2097	2423	2800	3237
	85	1928	2228	2575	2976	3439
	90	2041	2359	2727	3151	3642
	95	2155	2490	2878	3327	3845

Table 59.--Sawtimber stand volume, cubic feet, o.b., (VOS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (Years)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	VOS (cubic feet,o.b.,/acre)				
45	100	2269	2622	3030	3502	4047
	105	2382	2753	3182	3678	4250
	110	2496	2885	3334	3853	4453
	115	2610	3016	3486	4028	4656
	120	2723	3147	3637	4204	4859
	125	2837	3279	3789	4379	5061
	130	2951	3410	3941	4555	5264
	135	3064	3541	4093	4730	5467
	140	3178	3673	4245	4906	5670
	145	3292	3804	4397	5082	5873
	150	3405	3936	4549	5257	6076
	155	3519	4067	4701	5433	6279
	160	3633	4199	4853	5608	6482
	165	3747	4330	5005	5784	6685
	170	3860	4462	5156	5960	6888
50	10	239	276	319	369	426
	15	359	415	479	554	640
	20	479	553	639	739	854
	25	599	692	799	924	1068
	30	718	830	960	1109	1282
	35	838	969	1120	1294	1496
	40	958	1108	1280	1480	1710
	45	1079	1247	1441	1665	1924
	50	1199	1385	1601	1850	2139
	55	1319	1524	1761	2036	2353
	60	1439	1663	1922	2221	2567
	65	1559	1802	2082	2407	2782
	70	1679	1941	2243	2592	2996
	75	1799	2080	2403	2778	3210
	80	1920	2218	2564	2963	3425
	85	2040	2357	2725	3149	3639
	90	2160	2496	2885	3334	3854
	95	2280	2635	3046	3520	4068
	100	2400	2774	3206	3706	4283
	105	2521	2913	3367	3891	4497
	110	2641	3052	3528	4077	4712
	115	2761	3191	3688	4263	4927
	120	2882	3330	3849	4448	5141
	125	3002	3469	4010	4634	5356
	130	3122	3608	4170	4820	5570
	135	3242	3747	4331	5006	5785
	140	3363	3886	4492	5191	6000
	145	3483	4026	4652	5377	6214
	150	3603	4165	4813	5563	6429
	155	3724	4304	4974	5749	6644

Table 59.--Sawtimber stand volume, cubic feet, o.b., (VOS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (Years)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	VOS (cubic feet,o.b.,/acre)				
50	160	3844	4443	5135	5934	6859
	165	3964	4582	5295	6120	7073
	170	4085	4721	5456	6306	7288
	175	4205	4860	5617	6492	7503
55	15	376	434	502	580	670
	20	501	579	670	774	894
	25	627	724	837	968	1118
	30	752	870	1005	1162	1343
	35	878	1015	1173	1356	1567
	40	1004	1160	1341	1550	1791
	45	1130	1306	1509	1744	2015
	50	1255	1451	1677	1938	2240
	55	1381	1596	1845	2132	2464
	60	1507	1742	2013	2326	2689
	65	1633	1887	2181	2521	2913
	70	1759	2033	2349	2715	3138
	75	1884	2178	2517	2909	3362
	80	2010	2323	2685	3104	3587
	85	2136	2469	2853	3298	3811
	90	2262	2614	3022	3492	4036
	95	2388	2760	3190	3687	4261
	100	2514	2906	3358	3881	4485
	105	2640	3051	3526	4075	4710
	110	2766	3197	3695	4270	4935
	115	2892	3342	3863	4464	5160
	120	3018	3488	4031	4659	5384
	125	3144	3633	4199	4853	5609
	130	3270	3779	4368	5048	5834
	135	3396	3925	4536	5242	6059
	140	3522	4070	4704	5437	6284
	145	3648	4216	4873	5631	6509
	150	3774	4362	5041	5826	6733
	155	3900	4507	5209	6021	6958
	160	4026	4653	5378	6215	7183
	165	4152	4799	5546	6410	7408
	170	4278	4944	5714	6604	7633
	175	4404	5090	5883	6799	7858
	180	4530	5236	6051	6994	8083
60	15	391	451	522	603	697
	20	521	602	696	804	929
	25	651	753	870	1006	1162
	30	782	904	1045	1207	1395
	35	913	1055	1219	1409	1628
	40	1043	1206	1394	1611	1861
	45	1174	1357	1568	1812	2095

Table 59 --Sawtimber stand volume, cubic feet, o.b., (VOS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area

Age	Sawtimber basal area	Site index (Ft.)				
(years)	(Sq. ft.)	50	60	70	80	90
A	BS	VOS (cubic feet,o.b.,/acre)				
60	50	1305	1508	1743	2014	2328
	55	1435	1659	1917	2216	2561
	60	1566	1810	2092	2418	2794
	65	1697	1961	2267	2620	3028
	70	1828	2112	2441	2822	3261
	75	1959	2264	2616	3023	3494
	80	2089	2415	2791	3225	3728
	85	2220	2566	2966	3427	3961
	90	2351	2717	3140	3629	4195
	95	2482	2868	3315	3831	4428
	100	2613	3020	3490	4034	4662
	105	2744	3171	3665	4236	4895
	110	2875	3322	3840	4438	5129
	115	3005	3474	4015	4640	5362
	120	3136	3625	4189	4842	5596
	125	3267	3776	4364	5044	5830
	130	3398	3928	4539	5246	6063
	135	3529	4079	4714	5448	6297
	140	3660	4230	4889	5651	6531
	145	3791	4382	5064	5853	6764
	150	3922	4533	5239	6055	6998
	155	4053	4684	5414	6257	7232
	160	4184	4836	5589	6459	7465
	165	4315	4987	5764	6662	7699
	170	4446	5139	5939	6864	7933
	175	4577	5290	6114	7066	8167
	180	4708	5442	6289	7268	8400
	185	4839	5593	6464	7471	8634
65	15	403	466	539	623	720
	20	538	622	719	831	960
	25	673	778	899	1039	1201
	30	808	934	1079	1247	1442
	35	943	1090	1259	1456	1682
	40	1078	1246	1440	1664	1923
	45	1213	1402	1620	1872	2164
	50	1348	1558	1800	2081	2405
	55	1483	1714	1981	2289	2646
	60	1618	1870	2161	2498	2887
	65	1753	2026	2342	2706	3128
	70	1888	2182	2522	2915	3369
	75	2023	2339	2703	3124	3610
	80	2159	2495	2883	3332	3851
	85	2294	2651	3064	3541	4092
	90	2429	2807	3244	3750	4334
	95	2564	2963	3425	3958	4575

Table 59.--Sawtimber stand volume, cubic feet, o.b., (VOS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (Years)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	VOS (cubic feet,o.b.,/acre)				
65	100	2699	3120	3606	4167	4816
	105	2835	3276	3786	4376	5057
	110	2970	3432	3967	4585	5299
	115	3105	3589	4148	4794	5540
	120	3240	3745	4328	5002	5781
	125	3376	3901	4509	5211	6023
	130	3511	4058	4690	5420	6264
	135	3646	4214	4870	5629	6506
	140	3782	4370	5051	5838	6747
	145	3917	4527	5232	6047	6988
	150	4052	4683	5413	6256	7230
	155	4188	4840	5593	6465	7471
	160	4323	4996	5774	6673	7713
	165	4458	5153	5955	6882	7954
	170	4594	5309	6136	7091	8196
	175	4729	5465	6317	7300	8437
	180	4864	5622	6497	7509	8679
	185	5000	5778	6678	7718	8920
	190	5135	5935	6859	7927	9162
70	20	553	640	739	854	988
	25	692	800	925	1069	1235
	30	831	960	1110	1283	1482
	35	970	1121	1295	1497	1730
	40	1108	1281	1481	1711	1978
	45	1247	1441	1666	1925	2225
	50	1386	1602	1851	2140	2473
	55	1525	1762	2037	2354	2721
	60	1664	1923	2223	2569	2969
	65	1803	2084	2408	2783	3217
	70	1942	2244	2594	2998	3465
	75	2081	2405	2779	3212	3712
	80	2220	2565	2965	3427	3960
	85	2359	2726	3151	3641	4208
	90	2498	2887	3336	3856	4457
	95	2637	3047	3522	4071	4705
	100	2776	3208	3708	4285	4953
	105	2915	3369	3894	4500	5201
	110	3054	3530	4079	4715	5449
	115	3193	3690	4265	4929	5697
	120	3332	3851	4451	5144	5945
	125	3471	4012	4637	5359	6193
	130	3610	4173	4823	5574	6442
	135	3750	4334	5008	5788	6690
	140	3889	4494	5194	6003	6938
	145	4028	4655	5380	6218	7186

Table 59.--Sawtimber stand volume, cubic feet, o.b., (VOS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (years)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	VOS (cubic feet,o.b.,/acre)				
70	150	4167	4816	5566	6433	7435
	155	4306	4977	5752	6648	7683
	160	4445	5138	5938	6863	7931
	165	4585	5299	6124	7077	8180
	170	4724	5459	6310	7292	8428
	175	4863	5620	6496	7507	8676
	180	5002	5781	6682	7722	8925
	185	5141	5942	6867	7937	9173
	190	5281	6103	7053	8152	9422
	195	5420	6264	7239	8367	9670
	200	5559	6425	7425	8582	9918
75	20	567	655	757	875	1012
	25	709	820	947	1095	1265
	30	851	984	1137	1314	1519
	35	993	1148	1327	1534	1772
	40	1136	1312	1517	1753	2026
	45	1278	1477	1707	1973	2280
	50	1420	1641	1897	2192	2534
	55	1562	1806	2087	2412	2788
	60	1705	1970	2277	2632	3041
	65	1847	2135	2467	2851	3295
	70	1989	2299	2657	3071	3549
	75	2132	2464	2847	3291	3803
	80	2274	2628	3038	3511	4058
	85	2417	2793	3228	3731	4312
	90	2559	2958	3418	3951	4566
	95	2701	3122	3608	4170	4820
	100	2844	3287	3799	4390	5074
	105	2986	3451	3989	4610	5328
	110	3129	3616	4179	4830	5582
	115	3271	3781	4370	5050	5837
	120	3414	3946	4560	5270	6091
	125	3556	4110	4750	5490	6345
	130	3699	4275	4941	5710	6600
	135	3841	4440	5131	5930	6854
	140	3984	4605	5322	6150	7108
	145	4127	4769	5512	6370	7363
	150	4269	4934	5702	6591	7617
	155	4412	5099	5893	6811	7871
	160	4554	5264	6083	7031	8126
	165	4697	5428	6274	7251	8380
	170	4840	5593	6464	7471	8635
	175	4982	5758	6655	7691	8889
	180	5125	5923	6845	7911	9144
	185	5267	6088	7036	8132	9398

Table 59.--Sawtimber stand volume, cubic feet, o.b., (VOS) for natural, even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (Years)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	VOS (cubic feet,o.b.,/acre)				
75	190	5410	6253	7226	8352	9653
	195	5553	6417	7417	8572	9907
	200	5695	6582	7607	8792	10162
80	20	579	669	774	894	1033
	25	724	837	967	1118	1292
	30	869	1005	1161	1342	1551
	35	1015	1173	1355	1566	1810
	40	1160	1341	1549	1791	2069
	45	1305	1508	1743	2015	2329
	50	1451	1676	1937	2239	2588
	55	1596	1844	2132	2464	2847
	60	1741	2012	2326	2688	3107
	65	1887	2180	2520	2912	3366
	70	2032	2348	2714	3137	3625
	75	2177	2517	2908	3361	3885
	80	2323	2685	3103	3586	4144
	85	2468	2853	3297	3811	4404
	90	2614	3021	3491	4035	4664
	95	2759	3189	3686	4260	4923
	100	2905	3357	3880	4484	5183
	105	3050	3525	4074	4709	5442
	110	3196	3694	4269	4934	5702
	115	3341	3862	4463	5158	5962
	120	3487	4030	4658	5383	6221
	125	3633	4198	4852	5608	6481
	130	3778	4367	5047	5833	6741
	135	3924	4535	5241	6057	7001
	140	4069	4703	5436	6282	7261
	145	4215	4871	5630	6507	7520
	150	4361	5040	5825	6732	7780
	155	4506	5208	6019	6957	8040
	160	4652	5376	6214	7181	8300
	165	4798	5545	6408	7406	8560
	170	4943	5713	6603	7631	8820
	175	5089	5881	6797	7856	9079
	180	5235	6050	6992	8081	9339
	185	5380	6218	7187	8306	9599
	190	5526	6387	7381	8531	9859
	195	5672	6555	7576	8756	10119
	200	5817	6723	7770	8981	10379

Table 60.--Sawtimber stand volume, (BF, International 1/4-inch rule), for natural,even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age	Sawtimber basal area	Site index (Ft.)				
(Years)	(Sq. ft.)	50	60	70	80	90
A	BS	BF (board feet/acre)				
20	5	206	249	302	367	444
	10	417	506	614	744	902
	15	631	765	928	1125	1364
	20	847	1027	1245	1509	1830
	25	1063	1289	1563	1895	2298
	30	1281	1553	1883	2283	2767
	35	1499	1818	2204	2672	3239
	40	1718	2083	2525	3062	3712
25	5	278	337	408	495	600
	10	563	683	828	1004	1217
	15	852	1033	1253	1519	1841
	20	1143	1386	1680	2037	2470
	25	1436	1740	2110	2558	3101
	30	1729	2096	2542	3081	3736
	35	2024	2454	2975	3606	4372
	40	2319	2812	3409	4133	5011
	45	2616	3171	3845	4661	5651
	50	2913	3531	4281	5190	6292
	55	3210	3892	4718	5720	6935
	60	3508	4253	5157	6252	7579
	65	3807	4616	5596	6784	8225
	70	4106	4978	6035	7317	8871
	75	4406	5341	6476	7851	9518
	80	4706	5705	6917	8385	10166
30	5	339	411	499	604	733
	10	688	834	1012	1226	1487
	15	1041	1262	1530	1855	2249
	20	1396	1693	2052	2488	3016
	25	1753	2126	2577	3125	3788
	30	2112	2561	3104	3764	4563
	35	2472	2997	3633	4405	5340
	40	2833	3434	4164	5048	6120
	45	3195	3873	4696	5693	6902
	50	3558	4313	5229	6339	7686
	55	3921	4754	5763	6987	8471
	60	4285	5195	6298	7636	9258
	65	4650	5637	6835	8286	10046
	70	5015	6080	7372	8937	10835
	75	5381	6524	7909	9589	11626
	80	5748	6968	8448	10242	12417
	85	6115	7413	8987	10896	13210

Table 60.--Sawtimber stand volume, (BF, International 1/4-inch rule), for natural,even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (Years)	Sawtimber basal area (Sq ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	BF (board feet/acre)				
30	90	6482	7858	9527	11550	14003
	95	6850	8304	10068	12206	14798
	100	7218	8751	10609	12862	15593
	105	7586	9197	11151	13519	16389
	110	7955	9645	11693	14176	17186
	115	8325	10092	12236	14834	17984
	120	8694	10540	12779	15493	18783
35	5	391	474	575	697	845
	10	794	962	1167	1415	1715
	15	1201	1456	1765	2140	2594
	20	1611	1953	2367	2870	3480
	25	2023	2452	2973	3604	4370
	30	2436	2954	3581	4342	5264
	35	2852	3457	4191	5081	6160
	40	3268	3962	4803	5823	7060
	45	3685	4468	5417	6567	7962
	50	4104	4975	6032	7313	8866
	55	4523	5484	6648	8060	9772
	60	4943	5993	7266	8809	10679
	65	5364	6503	7884	9558	11588
	70	5786	7014	8504	10310	12499
	75	6208	7526	9124	11062	13411
	80	6630	8038	9745	11815	14324
	85	7054	8552	10368	12569	15238
	90	7477	9065	10990	13324	16154
	95	7902	9580	11614	14080	17070
	100	8326	10094	12238	14837	17988
	105	8751	10610	12863	15595	18906
	110	9177	11126	13489	16353	19826
	115	9603	11642	14115	17112	20746
	120	10029	12159	14741	17872	21667
	125	10456	12677	15369	18632	22589
	130	10883	13194	15996	19393	23512
	135	11311	13712	16624	20155	24435
	140	11738	14231	17253	20917	25359
	145	12166	14750	17882	21680	26284
	150	12595	15269	18512	22443	27209
	155	13023	15789	19142	23207	28135
	160	13452	16309	19773	23971	29062
40	10	884	1071	1299	1575	1909
	15	1337	1621	1965	2382	2888
	20	1793	2174	2635	3195	3873
	25	2251	2730	3309	4012	4864
	30	2712	3288	3986	4833	5859

Table 60.--Sawtimber stand volume, (BF, International 1/4-inch rule), for natural,even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (Years)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	BF (board feet/acre)				
40	35	3174	3848	4665	5656	6857
	40	3638	4410	5347	6482	7858
	45	4102	4973	6030	7310	8862
	50	4568	5538	6714	8140	9869
	55	5035	6104	7400	8972	10877
	60	5502	6671	8087	9805	11887
	65	5971	7239	8776	10640	12899
	70	6440	7807	9465	11476	13913
	75	6910	8377	10156	12313	14928
	80	7380	8948	10848	13151	15944
	85	7851	9519	11540	13991	16962
	90	8323	10091	12233	14831	17981
	95	8795	10663	12927	15673	19001
	100	9268	11236	13622	16515	20022
	105	9741	11810	14318	17358	21045
	110	10215	12384	15014	18203	22068
	115	10689	12959	15711	19047	23092
	120	11164	13534	16409	19893	24118
	125	11639	14110	17107	20739	25144
	130	12114	14687	17805	21587	26171
	135	12590	15263	18505	22434	27199
	140	13066	15841	19204	23283	28227
	145	13542	16418	19905	24132	29257
	150	14019	16996	20606	24981	30287
	155	14496	17575	21307	25832	31317
	160	14974	18154	22009	26683	32349
	165	15452	18733	22711	27534	33381
45	10	960	1164	1412	1711	2075
	15	1453	1761	2135	2589	3139
	20	1949	2362	2864	3472	4210
	25	2447	2967	3597	4361	5287
	30	2948	3574	4333	5253	6368
	35	3450	4183	5071	6148	7453
	40	3954	4793	5811	7045	8541
	45	4459	5406	6554	7945	9633
	50	4965	6019	7298	8847	10726
	55	5472	6634	8043	9751	11822
	60	5980	7251	8790	10657	12920
	65	6490	7868	9539	11564	14020
	70	7000	8486	10288	12473	15122
	75	7510	9105	11039	13383	16225
	80	8022	9725	11790	14294	17330
	85	8534	10346	12543	15207	18436
	90	9046	10967	13297	16120	19543
	95	9560	11590	14051	17035	20652

Table 60 --Sawtimber stand volume, (BF, International 1/4-inch rule), for natural,even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area

Age (Years)	Sawtimber basal area (Sq ft)	Site index (Ft)				
		50	60	70	80	90
A	BS	BF (board feet/acre)				
45	100	10073	12213	14806	17950	21762
	105	10588	12836	15562	18867	22874
	110	11103	13460	16319	19784	23986
	115	11618	14085	17076	20703	25099
	120	12134	14711	17835	21622	26214
	125	12650	15337	18593	22542	27329
	130	13167	15963	19353	23463	28445
	135	13684	16590	20113	24384	29562
	140	14201	17217	20873	25306	30680
	145	14719	17845	21635	26229	31799
	150	15238	18473	22396	27153	32919
	155	15756	19102	23159	28077	34039
	160	16275	19731	23921	29001	35160
	165	16794	20361	24685	29927	36282
	170	17314	20991	25448	30853	37405
50	10	1027	1245	1509	1829	2218
	15	1553	1883	2283	2767	3355
	20	2083	2525	3062	3712	4500
	25	2616	3171	3845	4661	5651
	30	3151	3820	4631	5615	6807
	35	3688	4471	5420	6571	7967
	40	4226	5124	6212	7531	9130
	45	4766	5778	7005	8493	10297
	50	5307	6434	7801	9457	11466
	55	5850	7092	8598	10424	12637
	60	6393	7750	9396	11392	13811
	65	6937	8410	10196	12361	14987
	70	7482	9071	10997	13333	16164
	75	8028	9733	11800	14306	17343
	80	8575	10396	12603	15280	18524
	85	9122	11059	13408	16255	19707
	90	9670	11724	14213	17232	20891
	95	10219	12389	15020	18209	22076
	100	10768	13055	15827	19188	23263
	105	11318	13721	16635	20168	24451
	110	11868	14388	17444	21148	25640
	115	12419	15056	18254	22130	26830
	120	12970	15725	19064	23113	28021
	125	13522	16394	19875	24096	29213
	130	14075	17063	20687	25080	30406
	135	14627	17734	21499	26065	31600
	140	15180	18404	22313	27051	32795
	145	15734	19075	23126	28037	33991
	150	16288	19747	23940	29024	35188
	155	16842	20419	24755	30012	36386

Table 60.--Sawtimber stand volume, (BF, International 1/4-inch rule), for natural,even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age	Sawtimber basal area	Site index (Ft.)				
(Years)	(Sq. ft.)	50	60	70	80	90
A	BS	BF (board feet/acre)				
50	160	17397	21092	25571	31001	37584
	165	17952	21765	26387	31990	38783
	170	18508	22438	27203	32980	39983
	175	19063	23112	28020	33970	41184
55	15	1640	1988	2411	2922	3543
	20	2200	2667	3233	3920	4752
	25	2762	3349	4060	4923	5968
	30	3328	4034	4891	5929	7189
	35	3895	4722	5724	6940	8414
	40	4463	5411	6560	7953	9642
	45	5033	6102	7398	8969	10874
	50	5605	6795	8238	9987	12108
	55	6177	7489	9080	11008	13346
	60	6751	8185	9923	12030	14585
	65	7326	8882	10768	13054	15827
	70	7902	9580	11614	14080	17070
	75	8478	10278	12461	15108	18316
	80	9055	10978	13310	16136	19563
	85	9633	11679	14159	17166	20812
	90	10212	12381	15010	18198	22062
	95	10792	13083	15862	19230	23314
	100	11372	13786	16714	20264	24567
	105	11952	14490	17568	21298	25821
	110	12533	15195	18422	22334	27077
	115	13115	15900	19277	23371	28334
	120	13698	16606	20133	24408	29592
	125	14280	17313	20989	25447	30851
	130	14864	18020	21847	26486	32111
	135	15447	18728	22705	27526	33372
	140	16032	19436	23563	28567	34634
	145	16616	20145	24423	29609	35897
	150	17201	20854	25283	30652	37161
	155	17787	21564	26143	31695	38426
	160	18372	22274	27004	32739	39691
	165	18959	22985	27866	33783	40958
	170	19545	23696	28728	34829	42225
	175	20132	24407	29591	35875	43493
	180	20719	25119	30454	36921	44762
60	15	1716	2081	2523	3058	3708
	20	2302	2791	3384	4102	4973
	25	2891	3505	4249	5152	6246
	30	3482	4222	5118	6205	7523
	35	4076	4941	5990	7263	8805
	40	4671	5663	6865	8323	10091
	45	5267	6386	7742	9386	11380

Table 60.--Sawtimber stand volume, (BF, International 1/4-inch rule), for natural,even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age	Sawtimber basal area	Site index (Ft.)				
(Years)	(Sq. ft.)	50	60	70	80	90
A	BS	BF (board feet/acre)				
60	50	5865	7111	8621	10452	12672
	55	6465	7838	9502	11520	13966
	60	7065	8566	10385	12590	15263
	65	7667	9295	11269	13662	16563
	70	8269	10025	12154	14735	17864
	75	8872	10756	13041	15810	19168
	80	9476	11489	13929	16887	20473
	85	10081	12222	14818	17965	21780
	90	10687	12957	15708	19044	23088
	95	11293	13692	16599	20124	24398
	100	11900	14428	17492	21206	25709
	105	12508	15164	18385	22289	27022
	110	13116	15902	19279	23373	28336
	115	13725	16640	20174	24458	29651
	120	14335	17379	21069	25543	30968
	125	14944	18118	21966	26630	32285
	130	15555	18858	22863	27718	33604
	135	16166	19599	23761	28807	34924
	140	16777	20340	24659	29896	36245
	145	17389	21082	25559	30986	37566
	150	18001	21824	26458	32077	38889
	155	18614	22567	27359	33169	40213
	160	19227	23310	28260	34261	41537
	165	19840	24054	29162	35355	42862
	170	20454	24798	30064	36448	44189
	175	21068	25543	30967	37543	45516
	180	21683	26288	31870	38638	46843
	185	22298	27033	32774	39734	48172
65	15	1784	2162	2622	3178	3853
	20	2392	2900	3516	4263	5168
	25	3004	3642	4416	5354	6490
	30	3619	4387	5319	6449	7818
	35	4235	5135	6225	7547	9150
	40	4854	5885	7134	8649	10486
	45	5474	6636	8046	9754	11826
	50	6095	7390	8959	10862	13168
	55	6718	8145	9875	11972	14514
	60	7342	8901	10792	13083	15862
	65	7967	9659	11710	14197	17212
	70	8593	10418	12631	15313	18565
	75	9220	11178	13552	16430	19919
	80	9848	11939	14475	17549	21275
	85	10477	12702	15399	18669	22634
	90	11106	13465	16324	19791	23993
	95	11736	14229	17250	20913	25355

Table 60.--Sawtimber stand volume, (BF, International 1/4-inch rule), for natural,even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (Years)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	BF (board feet/acre)				
65	100	12367	14993	18177	22038	26717
	105	12999	15759	19106	23163	28082
	110	13631	16525	20035	24289	29447
	115	14263	17292	20965	25417	30814
	120	14897	18060	21895	26545	32182
	125	15530	18828	22827	27674	33551
	130	16165	19598	23759	28805	34922
	135	16800	20367	24692	29936	36293
	140	17435	21137	25626	31068	37666
	145	18071	21908	26561	32201	39039
	150	18707	22680	27496	33335	40414
	155	19344	23452	28432	34470	41789
	160	19981	24224	29368	35605	43166
	165	20618	24997	30305	36741	44543
	170	21256	25770	31243	37878	45921
	175	21895	26544	32181	39015	47300
	180	22533	27318	33120	40153	48680
	185	23172	28093	34059	41292	50061
	190	23812	28868	34999	42431	51442
70	20	2473	2998	3634	4406	5342
	25	3105	3764	4564	5533	6708
	30	3740	4534	5497	6665	8080
	35	4377	5307	6434	7800	9457
	40	5017	6082	7373	8939	10838
	45	5657	6859	8315	10081	12222
	50	6300	7638	9260	11226	13610
	55	6943	8418	10206	12373	15000
	60	7588	9200	11153	13522	16394
	65	8234	9983	12103	14673	17789
	70	8881	10767	13054	15826	19187
	75	9529	11553	14006	16981	20587
	80	10178	12340	14960	18137	21989
	85	10828	13127	15915	19295	23392
	90	11478	13916	16871	20454	24798
	95	12130	14705	17828	21614	26204
	100	12782	15496	18787	22776	27613
	105	13434	16287	19746	23939	29023
	110	14088	17079	20706	25103	30434
	115	14741	17872	21667	26269	31847
	120	15396	18665	22629	27435	33261
	125	16051	19460	23592	28602	34676
	130	16707	20254	24556	29770	36092
	135	17363	21050	25520	30939	37510
	140	18019	21846	26485	32110	38928
	145	18676	22643	27451	33280	40348

Table 60.--Sawtimber stand volume, (BF, International 1/4-inch rule), for natural,even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (Years)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	BF (board feet/acre)				
70	150	19334	23440	28417	34452	41769
	155	19992	24238	29385	35625	43190
	160	20650	25036	30353	36798	44613
	165	21309	25835	31321	37972	46036
	170	21969	26634	32290	39147	47461
	175	22628	27434	33260	40323	48886
	180	23289	28234	34230	41499	50312
	185	23949	29035	35201	42676	51739
	190	24610	29836	36172	43854	53166
	195	25271	30638	37144	45032	54595
	200	25933	31440	38116	46211	56024
75	20	2544	3085	3740	4534	5496
	25	3195	3873	4696	5693	6902
	30	3849	4666	5657	6858	8314
	35	4504	5461	6620	8026	9731
	40	5162	6258	7587	9198	11152
	45	5821	7058	8556	10373	12576
	50	6482	7859	9528	11551	14004
	55	7145	8662	10501	12731	15435
	60	7808	9466	11477	13914	16869
	65	8473	10272	12454	15098	18305
	70	9139	11079	13432	16285	19743
	75	9805	11888	14412	17473	21183
	80	10473	12697	15394	18663	22626
	85	11142	13508	16376	19854	24070
	90	11811	14319	17360	21047	25516
	95	12481	15132	18345	22241	26964
	100	13152	15945	19331	23436	28413
	105	13824	16759	20318	24633	29864
	110	14496	17574	21306	25831	31316
	115	15169	18390	22295	27030	32770
	120	15842	19206	23285	28230	34225
	125	16516	20024	24276	29431	35681
	130	17191	20841	25267	30633	37138
	135	17866	21660	26260	31836	38597
	140	18542	22479	27253	33040	40057
	145	19218	23299	28247	34245	41517
	150	19894	24119	29241	35451	42979
	155	20571	24940	30236	36657	44442
	160	21249	25762	31232	37865	45906
	165	21927	26583	32229	39073	47371
	170	22605	27406	33226	40282	48836
	175	23284	28229	34224	41491	50303
	180	23964	29052	35222	42702	51770
	185	24643	29876	36221	43913	53238

Table 60.--Sawtimber stand volume, (BF, International 1/4-inch rule), for natural,even-aged longleaf pine in the East Gulf given stand age, site index, and sawtimber basal area.

Age (Years)	Sawtimber basal area (Sq. ft.)	Site index (Ft.)				
		50	60	70	80	90
A	BS	BF (board feet/acre)				
75	190	25323	30701	37220	45125	54707
	195	26004	31526	38221	46337	56177
	200	26684	32351	39221	47550	57648
80	20	2609	3163	3834	4648	5636
	25	3276	3972	4815	5837	7077
	30	3946	4784	5800	7031	8525
	35	4618	5599	6788	8230	9977
	40	5293	6417	7779	9431	11434
	45	5969	7236	8773	10636	12895
	50	6646	8058	9769	11844	14359
	55	7326	8881	10767	13054	15826
	60	8006	9706	11767	14266	17296
	65	8687	10532	12769	15481	18768
	70	9370	11360	13772	16697	20243
	75	10054	12189	14777	17915	21720
	80	10738	13019	15783	19135	23199
	85	11424	13850	16791	20357	24680
	90	12110	14682	17800	21580	26162
	95	12797	15515	18810	22804	27647
	100	13485	16349	19821	24030	29133
	105	14174	17183	20833	25257	30620
	110	14863	18019	21846	26485	32109
	115	15553	18855	22860	27714	33600
	120	16243	19693	23875	28945	35091
	125	16934	20531	24890	30176	36584
	130	17626	21369	25907	31409	38079
	135	18318	22208	26924	32642	39574
	140	19011	23048	27943	33877	41071
	145	19704	23889	28962	35112	42568
	150	20398	24730	29981	36348	44067
	155	21092	25571	31002	37585	45567
	160	21787	26414	32023	38823	47068
	165	22482	27256	33045	40062	48570
	170	23178	28100	34067	41302	50072
	175	23874	28944	35090	42542	51576
	180	24570	29788	36114	43783	53081
	185	25267	30633	37138	45025	54586
	190	25964	31478	38163	46267	56092
	195	26662	32324	39188	47510	57599
	200	27360	33170	40214	48754	59107

METRIC CONVERSION FACTORS

1 inch = 2.54 cm	1 acre = 0.4047 ha
1 foot = 0.3048 m	1 sq.ft./ac. = 0.2296 sq.m/ha
1 sq.ft. = 0.0929 sq.m	1 cu.ft./ac. = 0.006998 cu.m/ha
1 cu.ft. = 0.02832 cu.m	1 lb./cu.ft./ac. = 39.5774 kg/cu.m/ha

Farrar, Robert M., Jr. Volume and growth predictions for thinned even-aged natural longleaf pine stands in the east Gulf area. Res. Pap SO-220. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1985. 171 p.

A system of equations and resulting tables is presented for predicting current and future volumes for thinned even-aged naturally regenerated longleaf pine stands.

Additional keywords; *Pinus palustris;* growth, yield, production.

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Rating Stand Susceptibility to Southern Pine Beetle Attack on National Forests in the Gulf Coastal Plain

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CLEMSON

SUMMARY

Routine forest inventory data can be used to develop models for rating stand susceptibility to southern pine beetle (SPB) attack. Logistic regression models developed use data from the USDA Forest Service's Continuous Inventory of Stand Conditions to estimate the probability of SPB infestation. Models can be adjusted to allow for differences in stand conditions or varying SPB populations and should generally be applicable in stands of the National Forests in the Gulf Coastal Plain. The approach of using stand-level forest inventory information with historical records of SPB infestation occurrence can also be used to develop other statistically valid SPB risk-rating systems.

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INTRODUCTION

By predicting where insect and disease problems are most likely to occur, forest managers can plan and develop long-term management strategies for control of forest pests. Pest population monitoring can then be concentrated in areas where the probability of loss is greatest. Areas requiring preventive control can be identified and scheduled for treatment. Various risk-rating systems have been developed to make these predictions.

For a risk-rating system to be useful to forest managers, it must employ information that can be easily obtained, such as data from routine forest inventories. Lorio (1978) suggested that readily available information such as forest type, tree size and age (stand condition class), stand density, and site index could be used to develop a southern pine beetle (SPB), *Dendroctonus frontalis* Zimm., risk classification system. Such a system has been developed and implemented on the Kisatchie National Forest in Louisiana (Lorio and Sommers 1981) using data from the USDA Forest Service's Continuous Inventory of Stand Conditions (CISC) and has been extended to other Southern Region National Forests. This procedure uses existing forest resource data to place individual stands in one of three broad risk classes—high, medium, or low—and has proven useful for identifying stands where SPB infestations are most likely to occur in the National Forests of both Louisiana and Texas.

One disadvantage of the system is that stands within each risk class are considered equally likely to be infested by the SPB. A desirable characteristic would be the ability to rank stands in order of relative susceptibility to infestation; i.e., assign each stand a unique risk value. It would also be desirable to incorporate stand size in the risk-rating procedure. For instance, to optimize the effectiveness of a treatment on reducing the overall risk of SPB infestation for a management unit, a forest manager might choose to treat a large, medium-risk stand rather than a smaller, high-risk stand. Appropriate use of stand-size information should result in stands being ranked by their cummulative probability of infestation.

Therefore, the purpose of the present study was to develop quantitative models for predicting the probability of stand infestation by the SPB, based on routine forest inventory information (CISC). Furthermore, stand size is also incorporated into the calculation of stand risk.

METHODS

Historical information for the Kisatchie National Forest in Louisiana was combined with CISC data on the occurrence of SPB infestations in the same area to provide basic data for model development. Individual stand inventory information and SPB data for the Catahoula, Evangeline, Kisatchie, and Winn Ranger Districts for the period from January 1975 to June 1977 constituted the data base. This represents a 100-percent sample of the forest stands and SPB population for the four ranger districts.

Inventory variables included forest type, stand condition class, site index, stand age, and stand size (tables 1 and 2). Four forest types were defined: (1) loblolly and shortleaf pine, (2) slash and longleaf pine, (3) pine-hardwood, and (4) hardwood. To be included in the pine types, 70 percent or more of the dominant and codominant trees were pine of the appropriate species. The pine-hardwood type consisted of stands in which 31 to 69 percent of the dominants or codominants were pines. In the hardwood type, 70 percent of the dominant and codominant species were hardwoods. Three stand condition classes were defined: (1) sawtimber (d.b.h. $\geq$ 11 inches for pine and $\geq$ 13 inches for hardwood), (2) poletimber (d.b.h. $\geq$ 5 inches but smaller than sawtimber), and (3) seedling-sapling (d.b.h. $<$ 5 inches). Areas in the process of regeneration, nonstocked, or consisting of inadequately

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Table 1.—*Distribution of stands by stand condition class within forest type in the Kisatchie National Forest*

Forest type	Stand-condition class	Number of stands
Loblolly and Shortleaf	Sawtimber	1,825
	Poletimber	541
	Seedling & Sapling	623
	Total	2,989
Slash and Longleaf	Sawtimber	486
	Poletimber	287
	Seedling & Sapling	164
	Total	937
Pine-Hardwood	Sawtimber	409
	Poletimber	48
	Seedling & Sapling	5
	Total	462
Hardwood	Sawtimber	313
	Poletimber	109
	Seedling & Sapling	22
	Total	444

Table 2.—*Distribution of mean site index in feet (base age 50), stand age in years, and size in acres by forest type in the Kisatchie National Forest*

Forest type	Variable	Mean	Standard deviation	Minimum value	Maximum value
Loblolly and Shortleaf	size	123	144.9	1	988
	age	46	22.6	5	156
	site index	87	8.2	30	120
Slash and Longleaf	size	123	161.4	1	962
	age	43	17.4	4	131
	site index	80	11.3	40	100
Pine-Hardwood	size	73	79.7	1	629
	age	64	17.3	12	118
	site index	86	9.6	60	120
Hardwood	size	72	92.1	1	750
	age	59	18.7	7	134
	site index	84	10.5	50	120

stocked seedlings and saplings were excluded from the analysis.

Site index, by 10-foot classes, was on a 50-year basis. Stand age was the number of years since stand establishment, while stand size was expressed in acres. For a more detailed description of the data see Lorio and Sommers (1980).

Logistic regression models were developed for each forest type using the BMDPLR computer program (Dixon 1979). Coefficients were estimated using the method of maximum likelihood. A stepwise procedure was used to select variables based upon the criterion of a significant increase in the likelihood-ratio statistic. Two criteria for evaluating the adequacy of the models were the percentage of correct stand classification by infestation status and the degree of overlap of the predicted probabilities of infestation for attacked and nonattacked stands.

Each infested stand was weighted in the analysis by the number of infestations occurring in the stand during the study period. Thus, if a stand had three separate infestations, it was entered into the analysis as three separate observations. This weighting procedure was necessary to obtain an estimate of the actual probability of stand infestation as opposed to the probability of a stand having at least one infestation.

The models were used to classify stands as either infested or uninfested. A stand was classified as infested if the predicted probability of attack was equal to or greater than the actual mean probability of infestation for the host type; otherwise, the stand was considered uninfested. Using this procedure, a table of correct and incorrect classifications with regard to infestation status was generated.

RESULTS

Forest Type

Loblolly and Shortleaf Pine Type.—Stand condition class, site index, and stand size were significantly related to the probability of stand infestation (table 3). Sawtimber stands were most likely to be infested, followed by poletimber and then seedling-sapling stands. The probability of infestation increased as both site index and stand size increased. Seventeen percent of the stands in the loblolly and shortleaf pine type were infested. Stands were correctly classified with regard to infestation status 72 percent of the time. Uninfested stands were correctly classified at a slightly higher rate than infested stands (74 versus 71 percent).

Slash and Longleaf Pine Type.—For this forest type, stand size, age, and site index were all significantly related to the probability of infestation (table 3). Increases in the values of the all the variables resulted in increased probabilities. Infested stands comprised 10 percent of all the stands in this type. The model correctly classified a stand with regard to infestation status 72 percent of the time. Uninfested stands were correctly classified at a higher rate (74 percent) than infested stands (57 percent).

Pine-Hardwood Type.—Stand age and stand size were significantly related to the probability of infestation. In this forest type, 16 percent of the stands were infested. The model for this forest type correctly classified 69 percent of the stands. Uninfested stands were classified correctly (69 percent) more often than infested stands (54 percent).

Hardwood Type.—Stand size was the only variable significantly related to the probability of infestation,

Table 3.—*Logistic regression model coefficients for specified forest type and stand condition classes*

Forest type	Stand condition class	Coefficients[1]				Modified constant[2]
		B_0	B_1	B_2	B_3	B_m
Loblolly and Shortleaf	Sawtimber	4.222	−.0337	−.0068	.....	3.108
	Poletimber	4.532	−.0337	−.0068	.....	3.418
	Seedling & Sapling	5.706	−.0337	−.0068	.....	4.592
Slash and Longleaf	All classes	4.780	−.0243	−.0038	−.0109	2.886
Pine-Hardwood	All classes	2.820	.....	−.0091	−.0150	1.421
Hardwood	All classes	2.650	.....	−.0052	.....	0.361

[1] $\hat{P} = 1/(1 + EXP [B_0 + B_1X_1 + B_2X_2 + B_3X_3])$

where:

$\hat{P}$ = the estimated probability of infestation for period from June 1975 to June 1977,
X_1 = site index (base age 50) in feet,
X_2 = stand size in acres, and
X_3 = stand age in years from establishment.

[2] $B_m = B_0 - \ln(n/n_1)$

where:

n = the total number of stands used in developing the model and
n_1 = the number of infestations occurring in the n stands.

with probabilities increasing as stand size increased. Only a small number of the hardwood stands contained infestations (8 percent). The model for this forest type correctly classified 76 percent of the stands as being uninfested or infested. Uninfested stands were correctly classified (78 percent) at a higher rate than infested stands (60 percent). The ability of the model to adequately separate uninfested and infested stands was poor.

Defining Risk Classes

The logistic regression models are continuous functions, and division of the probability scale into discrete risk classes is somewhat arbitrary. One way of constructing classes is to classify stands as high risk if the predicted probability is greater than the median predicted probability for all infested stands and as low risk if the predicted probability is less than the median probability for the uninfested stands. Stands with predicted probabilities intermediate between these values are classified as medium risk. Using this method, stands with predicted probabilities less than 0.18 are classified as low risk, while stands with probabilities greater then 0.31 are classified as high risk. Stands with probabilities between 0.18 and 0.31 inclusive are considered as medium risk.

Estimating Probabilities

The generated probabilities of infestation are relative to the SPB population levels and stand conditions during the period of data collection. During the period from 1975 to 1977, beetle populations were very high; consequently, the predicted probabilities were also high. Furthermore, the models are based upon 2 years of data; therefore, the predicted probabilities are higher than would occur if the models had been based on data from a single year.

Estimates of the probabilities can be used to rank stands relative to one another, i.e., a stand with a probability higher than another is more likely to be attacked. In addition, the relative probabilities can be used to assign stands to the broad risk classes defined above. However, if absolute probabilities of infestation adjusted for the prevailing or predicted population levels are desired, the following procedure is used (Reed and others 1982):

$$P = 1/(1 + EXP [B_0 + B_i'X_i]) \quad (1)$$

where

P = the estimated probability of infestation for the period of June 1975 to June 1977,

B_0 = the constant,
B_i' = the estimated regression coefficient(s), and
X_i = the independent variable(s).

The constant, B_0, is modified to remove the effects of the beetle population and stand conditions prevailing at the time the model was developed:

$$B_m = B_0 - \ln (n/n_1) \quad (2)$$

where:

B_m = the modified constant,
n = the total number of stands used in developing the model,
n_1 = the number of beetle infestations for the period when the model was developed, and
ln = the natural logarithm.

Table 3 gives the values of the modified constant, B_m, for each forest type. B_m is then adjusted for the new beetle population level or stand conditions:

$$B_a = B_m + \ln (N/N_1) \quad (3)$$

where:

B_a = the adjusted constant,
B_m = the modified constant as defined in (2),
N = the total number of stands in the population of interest, and
N_1 = the total number of beetle infestations in the population of N stands.

The adjusted constant, B_a, is substituted for B_0 in equation (1). The resulting probabilities will be absolute in the sense that they represent the prevailing beetle population level and stand conditions.

A sample calculation for the loblolly and shortleaf pines follows. Values for the coefficients B_0, B_1, and B_2 are obtained from table 3. Assume that the stand consists of 123 acres of sawtimber with an average site index (50-year base) of 90 feet:

$$\hat{P}_a = 1/(1 + EXP [4.222 - 0.0337X_1 - 0.0068X_2])$$

$$= 1/(1 + EXP[4.222 - 0.0337(90) - 0.0068(123)])$$

$$= 1/(1 + EXP [0.3526])$$

$$= 0.4128$$

where:

$\hat{P}_a$ = the estimated probability of infestation,
X_1 = site index (50-year base) in feet, and
X_2 = stand size in acres.

The estimated probability, 0.4128, would hold for the beetle population levels and stand conditions occurring at the time the model was developed (1975–77). An adjusted probability of infestation for different conditions can be obtained using the adjusted constant. For instance, assume there are 1,000 loblolly or shortleaf stands with a total of 10 infestations in the population of interest. The adjusted probability of infestation for a stand with conditions as above ($X_1 = 90$, $X_2 = 123$) is then given by:

$$\hat{P}_a = 1/(1 + EXP [B_a - 0.0337X_1 - 0.0068X_2])$$

$$= 1/(1 + EXP [B_m + \ln (N/N_1) - 0.0337X_1 - 0.0068X_2])$$

$$= 1/(1 + EXP [3.108 + \ln (1000/10) - 0.0337(90) - 0.0068(123)])$$

$$= 1/(1 + EXP [3.844])$$

$$= 0.021$$

where:

$\hat{P}_a$ = the estimated adjusted probability of infestation,
B_a = the adjusted constant as defined in (3),
B_m = the modified constant as defined in (2) and obtained from table 3,
N = the total number of stands, and
N_1 = the number of infestations in N.

In this example, the unadjusted probability of infestation is almost 20 times larger than the adjusted estimate.

All of the sample calculations included stand size as a variable; however, information on stand size may not always be available, or comparisons of stands independent of size may sometimes be of interest. In these situations, the logistic regression equations can still be used by considering all stands equal in size, e.g., all stands assumed to be equal to 10 acres. All other calculations are as shown in the examples given above.

DISCUSSION

The results obtained from this study illustrate the utility of using routine forest inventory information for the development of SPB stand risk-rating systems. The variables included in the logistic regression models (forest type, site index, stand condition class, age, and size) were purposely chosen since they represent quantitative site/stand attributes that are not subject to judgment by foresters developing stand prescriptions. Furthermore, since the stands are re-entered on

a 10-year cycle for prescription purposes, it is useful to have variables that are not likely to change over the 10-year period. Except for age, which is known, stand condition class is the only one likely to change over the 10-year interval. Poletimber may become sawtimber, while seedling and saplings become poletimber. However, changes in condition class will only affect the loblolly and shortleaf pine type. The greatest increase in the probability of infestation will occur when a stand moves from the seedling and sapling class to the poletimber condition class. This large change is due to seedling or sapling size stands being less than 5 inches in d.b.h. Few stands with trees less than 4 inches in d.b.h. are successfully colonized by the SPB. Pine poletimber stands have trees between 5 and 11 inches in d.b.h., and these types of stands may be very susceptible to beetle infestation. Pine sawtimber trees are 11 inches or greater in d.b.h. These stands are generally the oldest and most susceptible to attack by SPB.

The models perform best for the forest types known to represent the most susceptible host species for the SPB; loblolly and shortleaf types and pine-hardwood types. Hardwoods are not attacked by the SPB, while slash and longleaf are low in susceptibility to attack. The model performance for stands with these least susceptible forest types is only fair to poor.

For the hardwood types, stand size is the only variable included in the model. The probability of infestation increases as stand acreage increases. This phenomenon is due to pockets of susceptible host types in very large stands.

In general, the risk-rating models perform best in stands that are homogeneous with respect to species, age, and stocking. Lumping of small stands to form a few large stands will result in poor predictability with regard to risk rating for SPB. As with all predictive models, the more accurate and precise the data, the more reliable the resulting predictions.

The models presented in this paper perform well when compared to Lorio and Sommer's (1981) subjective risk-rating system and therefore should be applicable whenever the subjective system is now in use in the Gulf Coastal Plain. Differences between the predictions of the two systems are due to differences in the variables included in each system, especially the inclusion of stand size in the logistic model and to the method used to develop the systems; i.e., statistical versus subjective analysis. The advantage of the logistic regression system is that each stand can be assigned a unique probability of infestation to which all other stands in a compartment or forest can be compared.

The methods presented in this paper can easily be used to develop statistically valid probability models for other geographical regions or other forest pests. All that is necessary is good stand level forest inventory data and a historical record of pest occurrence.

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Stand-level forest inventory information is combined with historical records to develop southern pine beetle risk-rating systems applicable to stands in National Forests on the Gulf Coastal Plain.

Keywords: Logistic regression models, inventory, *Dendroctonus frontalis*, SPB infestations.

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The Forests of Toro Negro

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SUMMARY

A forest inventory of the Toro Negro region, Puerto Rico, was conducted in 1983. Eight different forest classes were sampled: active coffee shade, abandoned coffee shade, secondary forest, eucalyptus plantation, other timberland, upper mountain forest, palm forest, and dwarf forest. The study found the region is 61 percent forested with 20,100 hectares of timberland and 2,300 hectares of other forest land. *Eucalyptus robusta* accounts for 19,000 cubic meters or 37 percent of the growing-stock volume in the public forest. Seven valuable hardwood species add 16,000 cubic meters to the growing stock on public timberland. Private timberland also includes valuable timber, but the large trees are more scattered and the average volume only one-third of that in public forests. Most eucalyptus plantations are ready for harvest and regeneration. Other public timberland contains good sapling and poletimber stocking and would benefit from release cutting. Private timberland has adequate sapling stocking, which could be released in many cases by removal of rough and rotten overstory trees.

CONTENTS

	Page
INTRODUCTION	1
STUDY AREA	1
METHODS	2
TORO NEGRO FORESTS	3
Forest Classification	3
Forest Area	3
Species Composition	4
Timber Volume	5
MANAGEMENT OPPORTUNITIES	6
LITERATURE CITED	7
APPENDIX	8
Reliability of the Data	8
Definitions	9
Species List	9
Unit Conversion Factors	13
Metric Inventory Standards	13
Tables	15

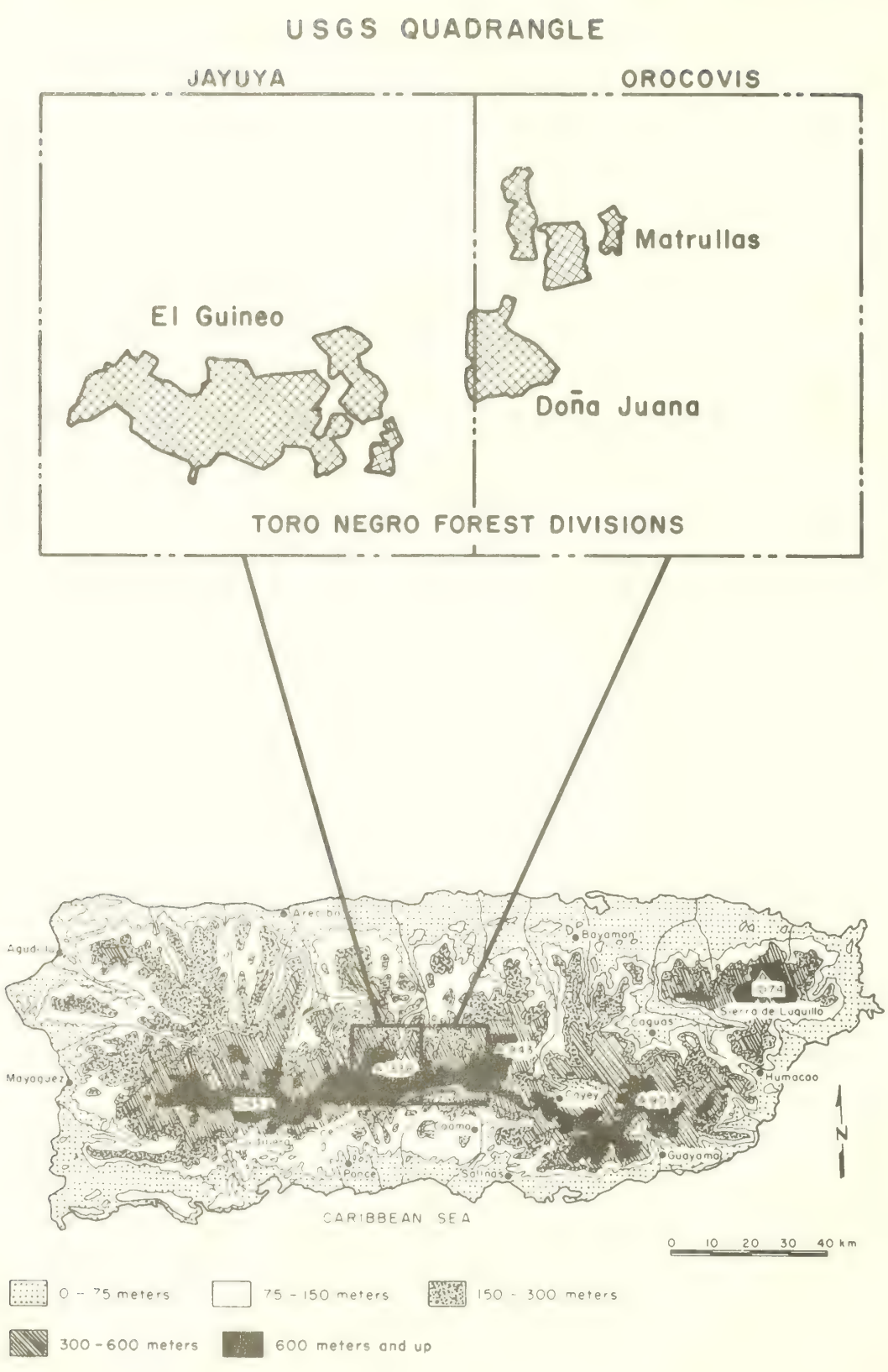

Figure 1.—*Major physiographic features of Puerto Rico, and location of study area.*

The Forests of Toro Negro

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INTRODUCTION

The Toro Negro forest inventory in Puerto Rico had two objectives: To develop field methods for subtropical and lower montane wet forests, and to provide a detailed assessment of the region's forest resources. Need for an evaluation of field methodology became evident after a 1980 survey of Puerto Rico's timberland (Birdsey and Weaver 1982). The Toro Negro region was chosen for study because it included an important Commonwealth Forest and a surrounding area with good forestry development potential. While the Luquillo Mountains of Puerto Rico have been studied intensively for many years (Brown et. al. 1983), data has been sparse for the Toro Negro highlands. Further, on a worldwide basis, little information covers the forest classes and conditions represented in Toro Negro, especially the secondary forest types.

The variety of forest cover types and diverse human impacts provided an appropriate area to test and evaluate field techniques. Similar forest conditions are found on most Caribbean islands and in countries bordering the Caribbean Sea (Lugo et. al. 1981). Thus the methodology and forest characteristics reported here may have some regional significance.

The data will be used to guide management decisions within the Toro Negro Commonwealth Forest, and to promote forestry development in the surrounding region. The information will also contribute to the growing pool of knowledge about tropical forests and their role in the biosphere, by providing information about forest recovery after extensive deforestation and about management opportunities in secondary forests. Current data may be used to develop biomass estimates, and subsequent surveys may be used to estimate productivity.

This paper presents a detailed assessment of the forests of the Toro Negro region. Field methods, while outlined, will be analyzed in detail elsewhere.

STUDY AREA

The inventory was conducted within the boundaries of two U.S. Geological Survey quadrangle maps, Jayuya and Orocovis, located between 18°07′30″ and 18°15′00″ latitude, and 66°22′30″ and 66°37′30″ longitude. The region straddles Puerto Rico's central mountain range and includes the Toro Negro Commonwealth Forest, which has three major divisions, El Guineo, Doña Juana, and Matrullas (fig. 1).

The Toro Negro region includes three forest life zones: subtropical moist, subtropical wet, and lower montane wet (Ewel and Whitmore 1973; Holdridge 1967). Average annual rainfall ranges from about 1600 to 2900 millimeters (Commonwealth of Puerto Rico 1979). Elevation ranges from 140 meters near the town of Villalba to 1338 meters at Cerro de Punta, the highest point on the island. Average annual temperature ranges from about 20 to 24 degrees centigrade. Rainfall usually declines between November and April, but there is seldom a prolonged dry period. Occasional hurricanes or intense rainstorms strongly influence the character of the vegetation by causing landslides or toppling trees.

The central mountains run from east to west and form the island's principal hydrologic divide. The area of the Toro Negro Forest consists of a complex of mountain ranges of volcanic origin that were eroded during the Cretaceous period to an advanced stage of topographic development. Uplift and subsequent erosion have cut the entire area into a complex series of valleys and intervening narrow ridges. Steep slopes, rugged terrain, and numerous streams and gorges characterize the topography. Most of the soils are deep or shallow clays, with an area of granitic intrusion producing sandy clays in the northwestern part of the study area. Soil depth varies greatly over short distances depending on weathering and erosion. The most common soil orders are Inceptisols and Ultisols.

The Toro Negro Forest is located on the island di-

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vide and presently protects the headwaters of four rivers that flow to the south coast and three that flow to the north coast. Water for power and irrigation is stored in the Guineo and Matrullas reservoirs. Both reservoirs and the entire Toro Negro forest are especially critical for soil and water conservation.

The Toro Negro Forest was designated in 1935 as a purchase unit of the Caribbean National Forest. Most of the region, including the accessible parts of the Toro Negro Forest, was cultivated or pastured at that time. Coffee production under tree shade was common, although marginal areas in the higher elevations had already been abandoned to other crops. Most of the accessible timber in the region has been cut. At the time of purchase, there were about 15 families living within the Toro Negro Forest, farming degraded lands (Wadsworth and Solis 1949).

Changes occurred in the Toro Negro Forest under National Forest management. Mature timber and charcoal wood were harvested regularly, and the better sites were planted with *Eucalyptus robusta* (eucalyptus), *Swietenia macrophylla* (mahogany), and *Montezuma speciosissima* (maga). Roads were constructed to open up the more remote areas, a public recreation area was developed, and some farming was allowed to continue. Additional settlement within the public forest was encouraged under the Civilian Conservation Corps relief program, and later under local employment programs. These programs were intended to provide forestry employment and accomplish reforestation goals (Wadsworth and Solis 1949). After 1955 a new series of plantings with additional species such as *Pinus caribaea* Morlet (pine), *Hibiscus elatus* Sw. (mahoe) and *Anthocephalus chinensis* (Lam.) A. Rich ex Walp. (kadam) were initiated (Watson 1982).

In April, 1970, the Puerto Rican Department of Agriculture purchased 1,677 acres of forest land adjacent to the Luquillo Division of the Caribbean National Forest, and exchanged this with the U.S. Forest Service for complete transfer of the Toro Negro Division to the Commonwealth of Puerto Rico. The Department of Natural Resources was legally created in 1972, and by 1973 the Puerto Rican Department of Agriculture transferred the property titles of the Toro Negro forest to the Department of Natural Resources. The Commonwealth continues to protect the forest from encroachment, and regulates disturbances that may affect watershed protection.

Current nonforest land uses in the region surrounding the Toro Negro Forest include unimproved pasture, coffee production (under shade and shadeless), and production of crops such as plantains, taniers, yams, bananas, oranges, mango, avocado, or other garden crops planted in various mixtures. Small farms are interspersed with coffee plantations and forests in various successional stages, giving the region a characteristic patchwork appearance. The public forest contains successional types and plantations, as well as some extensive, relatively undisturbed high elevation forests, especially in the El Guineo division. These natural forests include the dwarf and palm types, and the colorado and tabonuco types which are described elsewhere (Little and Wadsworth 1964).

METHODS

The data on forest acreage, timber volume, and species composition were obtained by a sampling method involving both a land cover classification on aerial photographs and on-the-ground measurements. A dot count method was used to obtain an initial estimate of area by land cover class. This estimate was adjusted on the basis of a ground check of actual land cover at each of the sample locations.

Ground sample locations were selected on U.S. Geological Survey topographic maps and transferred to the aerial photographs. The center of each forest location was determined on the ground by running a computed azimuth and distance from a selected starting point. Each plot at a sample location was marked so that future surveys can reestablish the plot and estimate growth, mortality, removals, and changes in land use.

The field survey was designed with several levels of detail. The region bounded by the 2 USGS quadrangles was sampled to provide some data about private forest lands. Field sample locations were selected at the intersections of the same grid of lines used in the 1980 survey. Sample locations measured in 1980 were not remeasured in 1983. Grid spacing was 3 kilometers and each sample location represented about 900 hectares.

The sample was intensified in the public forests to provide enough detail to formulate broad management guidelines, to characterize the major forest classes, and to select enough sample trees to estimate timber volume with a standard error of approximately 10 percent. The minimum number of plot locations required was estimated by reviewing statistics from similar plot locations measured in 1980. Actual sampling errors for each division and for public and private forests are discussed in the appendix.

Two sampling intensities were used in the public forest. The lower intensity survey was used for El Guineo division, which is composed principally of high elevation, noncommercial forests that are somewhat less diverse than forests at lower elevation. Each field sample location in El Guineo represented approximately 56 hectares, and detailed measurements were taken on half of these plots. All locations were visited to check current cover condition.

The Doña Juana and Matrullas divisions were sam-

pled at twice the intensity of the El Guineo division because most of the forest area is managed for timber production. Each field sample location was selected to represent approximately 28 hectares. This intensity allowed the crude delineation of stand boundaries, and preparation of a preliminary stand map to guide future management compartment selection.

A total of 41 field sample locations were visited on private land, 18 of which were forested. Five of the forested locations had been measured in 1980. On public land, 64 sample locations were visited, 62 were forested, and 40 were measured. Due to steep and rugged terrain, four sample locations were inaccessible for detailed tree measurement.

A cluster of 3 permanent sample plots was established at each sample location. Sample plots were located 25 meters apart. At each sample plot, trees larger than 12.5 centimeters in diameter at breast height (d.b.h.) were tallied on a variable-radius plot, with each tree representing 2.5 square meters of basal area per hectare. Trees less than 12.5 centimeters d.b.h. were tallied on a fixed radius plot of approximately 40 square meters around the plot center.

Each sample location was classified by numerous site characteristics. Each sample tree 12.5 centimeters and larger was measured and assessed to determine timber volume and quality. Species was accurately determined for all sample trees. Detailed field measurements were assembled into a handbook (Birdsey 1982). All definitions and inventory standards are listed in the appendix, along with a species list and some useful conversion factors.

In this study, all field data were recorded on tally sheets, transferred to the computer, and edited for errors prior to compilation. Errors were kept to a minimum by careful training, diligent field work, and a detailed edit procedure that checks all items for consistency and reasonableness.

All field work was done during 1983. Photointerpretation for area estimation was done prior to field work, using 1:20,000 scale panchromatic photography acquired during 1977.

TORO NEGRO FORESTS

Forest Classification

Public timberland is composed of plantations and "other timberland", a catch-all category including a variety of forest classes on productive sites, none extensive enough to be treated independently in this study. Other timberland includes abandoned coffee shade, reverting pasture and cropland, older secondary forests, partially successful plantations, and other disturbed timberland that could not be classified as plantation.

All of the plantations sampled are forests in which Eucalyptus comprised at least 25 percent of current basal area. Although other plantation species are found, they are restricted to very small parcels, or had poor survival rates.

Timberland classes tend to occur on moderate sites that are reasonably accessible (table 1). Noncommercial forest classes are located in relatively inaccessible, high elevation regions where climatic extremes preclude agricultural development and produce forests with undesirable timber characteristics. The noncommercial forest classes include the upper mountain or colorado type, the palm forest, and the dwarf forest occupying the highest exposed ridges and mountaintops.

Only a small proportion of private forests in the Toro Negro region was classed as noncommercial. Private timberland forests included 3 principal classes: secondary forests or volunteer stands, abandoned coffee shade, ar[illegible]ctive coffee shade. The principal physiographic difference among these classes is that coffee production u[illegible]er shade trees is currently restricted to the better, lo[illegible] elevation sites (table 2).

The forest [illegible]asses have significant structural differences. Public [illegible]imberland has higher stocking and volume than pr[illegible]ate timberland, especially the plantations with m[illegible]re than 3 times the average timber volume (tables 3 and 4). A comparison of public "other timberland" with all private classes shows the current poorly-stocked nature of most private forests. Among the noncommercial forest classes, palm forest shows a high mean diameter which reflects the high number of stems in the 20 cm. diameter class (table 5).

Forest Area

The Toro Negro region is 61 percent forested, compared with about 31 percent forest cover for the whole island (Birdsey and Weaver 1982). Timberland totals 20,000 hectares, mostly in private ownership (table 6). The relatively few hectares of other forest land are extremely important because this cover protects some critical watersheds in the upper mountain regions. Sixty-five percent of other forest land is protected under public ownership. Toro Negro water supplies cities and towns throughout central Puerto Rico, provides hydroelectric power, and is used for irrigation in the dry, southern region.

Most of the manageable public timberland is found in the Doña Juana and Matrullas forest divisions (table 7). Most of the noncommercial forest classes are located in the El Guineo division, with the exception of about 150 hectares of palm forest scattered elsewhere. Timberland in El Guineo consists of scattered plantation remnants, abandoned coffee shade, and other isolated tracts on the fringes of the division. This area was not intensively sampled and is excluded from subsequent discussion.

All of the public timberland is located within the subtropical wet forest life zone (table 8). The more extreme climate of the lower montane wet forest life zone precludes development of commercial timber stands. Instead, this life zone is characterized by the dwarf and palm forest classes, with pockets of upper mountain forest developing on protected ridges and upper slopes. The palm type is the only noncommercial forest class found in the subtropical wet forest life zone.

A small portion of the private timberland extends into a third life zone, the subtropical moist forest, in the lowest and driest portions of the region (table 9). Secondary forests are most common and account for 59 percent of the private timberland.

Most of the noncommercial forest area has been spared human disturbance for the past 35 years, and probably much longer (table 10). In contrast, more than half of the timberland in Doña Juana and Matrullas was still in coffee shade, pasture, or early succession brush in 1950. These past uses can still be identified from residual species characteristic of the small farms common at that time.

The Doña Juana division contains some small, relatively undisturbed tracts of mature timber. A small area of Tabonuco forest in the northwest corner is one of the few remnants of this type under public ownership in the Central Cordillera. The tract borders a much larger one in private ownership.

Species Composition

Current species composition in each forest class is strongly influenced by past land use practices, and by site conditions which are quite variable in the Toro Negro region. *Eucalyptus* plantations have the least complex overstory, with *Eucalyptus robusta* accounting for 63 percent of the total basal area and dominating the sawtimber size class (table 11). The next most common species, *Micropholis chrysophylloides* (caimitillo), totals only 4 percent of the basal area but is relatively common in the poletimber class. A few species are common in the understory: *Eugenia jambos* (pomarrosa) has edible fruits but little timber value; *Nephelea portoricensis* (helecho gigante espinosa) is the common tree fern of the area; and *Tabebuia heterophylla* (roble blanco) and *Alchornea latifolia* (achiotillo) are the most common timber species.

Other public timberland has a much more complex composition which reflects the various cover types and sites which compose this class (table 12). *Prestoea montana* (palma de sierra) and *Cecropia peltata* (yagrumo hembra) are the most common species. The most common saplings are the same as plantation forests, with the addition of *Casearia arborea* (rabo ratōn). Some of the more common species produce high quality cabinet timber.

Composition of the upper mountain forest is similar to the Colorado forest of the Luquillo Mountains, except that *Cyrilla racemiflora* (palo colorado) does not dominate the overstory (table 13). *Prestoea* and *Micropholis* together account for 43 percent of the basal area. Tree ferns and *Matayba domingensis* (negra lora) are also common in the understory.

The palm forest is one of the few vegetation associations in Puerto Rico dominated by a single species. *Prestoea* accounts for 60 percent of the basal area and 73 percent of the trees in the poletimber class (table 14). These percentages are remarkably similar to those reported for palm forest in the Luquillo Mountains (Brown et. al. 1983). Other abundant species such as the tree fern are those found throughout the Toro Negro uplands.

The dwarf forest includes species found in other classes, but of much smaller size and with different rates of occurrence. The composition is also quite different from the dwarf forest in the Luquillo Mountains. Three tree fern species (*Cyathea arborea*, *C. aquilina*, and *Nephelea portoricensis*) together account for 34 percent of the basal area (table 15). *Prestoea* is again common, along with two species less common in other classes, *Clusia grisebachiana* and *Calycogonium squamulosum*. Occasional sawtimber-size trees appear in protected pockets.

Private timberland species composition is most similar to that found elsewhere on the island, except for a higher abundance of *Prestoea* (table 16; Birdsey and Weaver 1982). Most of the species are typical of secondary or coffee shade forests. The most common sapling is *Coffea arabica* (coffee), with many individuals persisting for years after plantation abandonment, and others established as volunteers in secondary forests. Despite the prevalence of *Prestoea* in the Toro Negro region, it is never found on active or abandoned coffee shade sample plots. Thus the absence of palm and the presence of residual coffee saplings is a good indicator that coffee was once cultivated.

Seedling occurrence may foretell future forest composition, although major disturbances may radically alter the site conditions, introduce new seeds, or prompt others to germinate. With this uncertainty in mind, it may be useful to note that *Prestoea* is the most common seedling in plantations while being relatively scarce among larger tree size classes (table 17). A variety of sapling species is found in other public timberland. The small understory species *Daphnopsis philippiana* is most common in the upper mountain forest, and found along with the *Prestoea* in the palm forest. Another understory species, *Myrcia deflexa*, is prevalent among seedlings in the dwarf forest.

Timber Volume

Eucalyptus robusta dominates public timberland, accounting for 82 percent of plantation growing-stock volume and 37 percent of all public growing-stock volume in Doña Juana and Matrullas (tables 18 and 19). Most of the volume is in large sawlogs in trees greater than 30 centimeters d.b.h. Although *Eucalyptus* can be used as utility lumber, its tendency to warp unevenly limits usefulness. Altogether more than 19,000 cubic meters of *Eucalyptus* growing stock are available for harvest.

About 16,000 cubic meters of valuable hardwood growing stock are also available from seven common species in Doña Juana and Matrullas (fig. 2). A high proportion of this is in poletimber, although the percentage varies for each species (tables 18 and 19). There are many additional species which contain cabinet-quality or utility timber, but none are particularly common throughout the area.

The most valuable growing stock found on private timberland includes *Guarea guidonia* (guaraguao) and *Inga fagifolia* (guama), both common in public timberland, and *Andira inermis* (moca), *Montezuma speciossima* (maga), and *Cordia alliodora* (capa prieto; table 20). Much of this is available in large sizes, with the exception of *Andira*. Although the volumes are much larger on private land, the large trees are more scattered and availability is more questionable. The average timber volume in public plantations is 184.5 cubic meters per hectare, more than 3 times the average of 58.4 cubic meters on private timberland. Other public timberland averages 124.6 cubic meters per hectare.

A comparison of diameter distributions for the 3 timberland classes illustrates the differences among stand structure (fig. 3). The *Eucalyptus* plantations are reaching maturity, the other public timberland is composed of mixed ages, and the private timberland tends toward the younger age classes. The plantations appear somewhat erratic due to an irregular planting history.

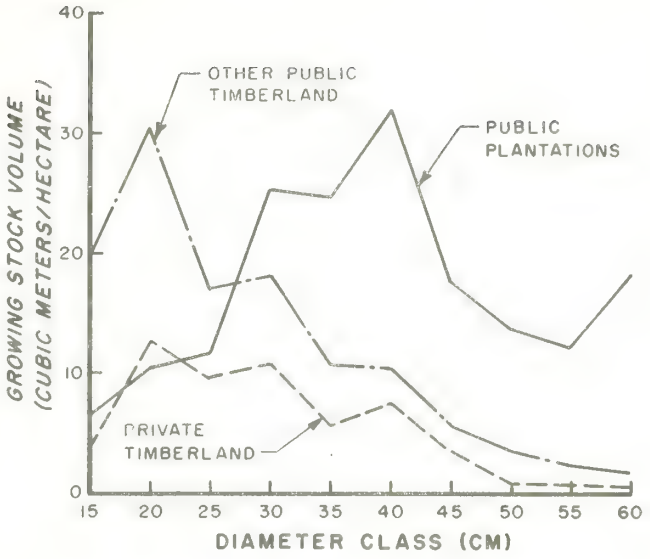

Figure 3.—*Growing-stock volume by diameter class, Toro Negro timberland.*

The potential uses of standing timber strongly affect marketability, and will ultimately determine the feasibility of developing a timber industry in the region. Other public timberland contains the highest concentration of quality sawtimber species with an average of 41 cubic meters per hectare (table 21). Most of the unusable timber in this forest class is *Prestoea montana* and *Eugenia jambos*.

Another important factor affecting the economics of timber utilization is tree quality. *Eucalyptus* plantations are clearly desirable from this standpoint since most of the volume is in large sawlogs. The favorable species mix found on private timberland is somewhat tempered by the high percentage of timber in rough

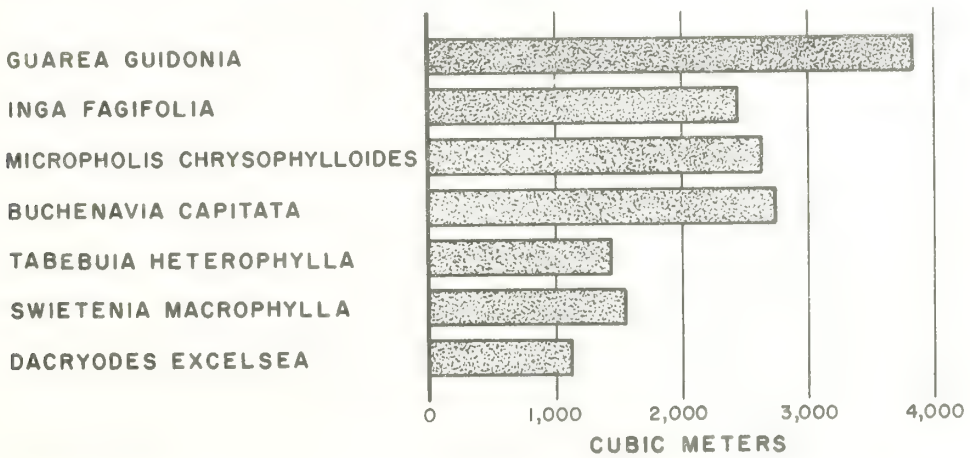

Figure 2.—*Growing-stock volume of some common valuable timber species in Doña Juana and Matrullas.*

and rotten trees (table 22). This wood is often uneconomical to recover. Poletimber trees on other public timberland contain a particularly high percentage of sound cull volume.

Yet another factor that must be considered is accessibility. Site characteristics indicate a range of slope classes from 20 to 90 percent, and a range of hauling distances from 0 to 800 meters for timberland. Many tracts would require access roads, special logging equipment for steep slopes, and great care to avoid site degradation.

In sum, the most immediate utilization problem for public timberland is to find a suitable market for the mature *Eucalyptus*. Harvesting the large stems would primarily be limited by equipment availability and access. Much of the sawtimber of other species is scattered. Extensive harvesting on private timberland should be deferred until promising young stands mature. In all cases, timber harvesting should be done within the context of a management plan which ensures a future timber stand and preserves the many valuable non-timber attributes of the Toro Negro forest.

MANAGEMENT OPPORTUNITIES

Forest inventory data can provide guidelines for developing a timber management strategy for Toro Negro timberlands. These broad guidelines should not be directly applied to a particular stand of timber without a detailed stand examination to determine if the actual composition is similar to this characterization of the whole forest.

The first step to develop a timber management plan is to tally the number of trees by size class, and attach a use code to the more common species. Then the number of sapling and poletimber trees can be compared to a standard to decide if there is sufficient stocking of desirable species to establish a manageable timber stand. In the absence of stocking guides developed through experimentation, a local "rule-of-thumb" can be used. For Puerto Rico, a minimum stocking per hectare of 100 poletimber trees or 250 saplings of desirable species can be considered adequate for a manageable stand (Wadsworth and Birdsey 1982).

Toro Negro plantations are dominated by mature *Eucalyptus* which is ready for harvest. The timber could be replaced by artificial or natural regeneration. Currently, poletimber stocking of high quality sawtimber species averages 72 trees per hectare, chiefly *Micropholis* and *Guarea* (table 23). Utility species provide an additional 110 poletimber trees per hectare. Total utilizable sapling stocking averages about 190 trees per hectare. Saplings and poletimber together clearly exceed minimum stocking, however, harvesting large eucalyptus logs would probably cause excessive damage to residual trees, making the after-harvest stocking closer to borderline conditions. Considering the actual understory variability from stand to stand, each case would have to be evaluated separately. Most likely a mixture of artificial and natural regeneration would be prescribed.

Additional consideration must be given to the ecological characteristics of the resultant species mix. Do *Eucalyptus* and *Micropholis* have compatible growth rates? There may also be opportunities to deaden undesirable competitors such as *Eugenia jambos*. Common understory species such as the tree ferns could be left since many do not affect timber volume growth significantly, and may have other important roles in the forest ecosystem.

Other public timberland lacks the dominance of a single, harvestable species, making selective harvests of a few valuable stems much more likely. This could be coupled with timber stand improvement treatments that would favor the currently adequate stocking of desirable immature trees of *Guarea*, *Inga fagifolia*, *Micropholis*, and *Tabebuia* (table 24). High quality growing stock averages 249 saplings and 105 poletimber trees per hectare, with utility timber species adding another 225 saplings and 116 poletimber trees. Common desirable species comprise 20 percent of all saplings and 48 percent of all poletimber. Many of the less desirable species are small understory trees and would not compete with the desirable timber species. Conversion of other public timberland to plantation species would probably not be warranted due to the adequacy of current stocking.

Private timberland has adequate sapling stocking but lacks a good poletimber component (table 25). An additional problem concerns the high proportion of rough and rotten poletimber and sawtimber trees (table 26). Poor tree quality renders many of the sawtimber trees undesirable for harvest, and cull poletimber cannot be considered part of the manageable stand. These trees must be deadened along with undesirable saplings to release the good saplings and establish a timber stand.

Although there is more uncertainty when relying on saplings for a future stand, many private stands include sufficient stocking to warrant close inspection. *Guarea* is particularly common and could be featured as the principal species in many private forests.

Timber management in the Toro Negro region will always be subject to the constraints of management for other forest resources. The value of forest cover for watershed protection increases each year as island population grows. Every forest disturbance will affect the water supply, and so every management activity must be evaluated carefully. Both public and private owners control critical forest watersheds and, although the most critical areas are not suitable for timber production, they are surrounded by timber-

lands which must be carefully managed if brought into production.

The Toro Negro Forest includes recreation sites and hiking trails that make the unique forests accessible to all. The cool climate and scenic beauty attract many visitors each year. Forest management to enhance these qualities is essential, and produces returns that cannot be measured in dollars.

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APPENDIX

Reliability of the Data

Reliability of the estimates may be affected by two types of errors. The first stems from the use of a sample to estimate the whole and from variability of the items being sampled. This is termed "sampling error"; it is expressed in a mathematical evaluation of the probability of error. The second type—referred to as "reporting error" or "estimating error"—derives from mistakes in measurement, judgment, or recording, and from limitations of methods or equipment. This type of error is held to a minimum by proper staff training, supervision, and precision.

Statistical analysis of the data indicates a sampling error of plus or minus 3.5 percent for private forest area and 0.4 percent for public forest area. Timber volume sampling errors were estimated to be 26.5 percent for private forests and 9.8 percent for public forests. As these totals are broken down by species, tree size, or other classifications, the possibility for error increases and is greatest for the smallest subdivisions. The order of this increase is suggested in the following tabulation, which includes sampling error estimates for area and volume by land class and forest division:

Forest area and timber volume sampling errors[1] by owner, forest division, and land class, Toro Negro region, 1983

Owner and forest division	Land class		Total forest	Timber volume
	Timberland	Other forest land		
	percent			
Public				
El Guineo	3.7	3.7	0.5	--
Doña Juana	9.0	8.9	0.7	12.9
Matrullas	9.6	9.4	0.9	13.9
Total	4.2	4.2	0.4	9.8
Private				
Total	3.5	0.5	3.5	26.5

[1]Standard error.

DEFINITIONS

Forest land—Land at least 10 percent stocked by forest trees of any size, or formerly having had such tree cover and not currently developed for nonforest use. The minimum area for classification of forest land is 1/2 hectare, and the minimum width for forest strips is 35 meters. Unimproved roads and trails, streams, and clearings in forest areas are classed as forest if less than 35 meters in width.

Timberland—Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization.

Nonstocked land—Commercial forest land less than 10 percent stocked with growing-stock trees. This includes areas covered by inhibiting vegetation (brush, vines, ferns, etc.) classed as forest land.

Secondary forest land—Forest land resulting from the abandonment of cropland or pasture, and forest resulting from the regeneration of previously cutover or disturbed forest land. Abandoned coffee shade is excluded from this class.

Coffee shade—A multi-story, multi-crop system used principally for the production of coffee. An upper story of shade trees is characteristic.

Abandoned coffee shade—Secondary forest land resulting from the abandonment of coffee production under shade trees.

Growing-stock trees—Sawtimber trees, poletimber trees, saplings, and seedlings; that is, all live trees except rough and rotten trees.

Rough and rotten trees—Live trees that are unmerchantable for sawlogs now or prospectively because of defect or rot.

Sawtimber trees—Growing-stock trees, 22.5 centimeters and larger in d.b.h. for softwoods and 27.5 centimeters and larger for hardwoods, and containing at least one 3.5 meter sawlog.

Poletimber trees—Growing-stock trees 12.5 to 22.5 centimeters in d.b.h. for softwoods and 12.5 to 27.5 centimeters for hardwoods, and of good form and vigor.

Saplings—Growing-stock trees 2.5 to 12.5 centimeters in d.b.h., and of good form and vigor.

Volume of sawtimber—Net volume of the sawlog portion of sawtimber trees in cubic meters, calculated according to the International rule, 0.635 centimeter (1/4 inch) kerf.

Volume of growing stock—Volume of sound wood (less cull volume) in the bole and branches of sawtimber and poletimber trees from stump to a minimum 10 centimeter diameter outside bark or to the point past which a one-meter section meeting minimum qualifications can no longer be measured because of limbs or other cull.

Volume of timber—Volume of all sound wood (including sound cull) in the bole and branches of growing stock, rough, rotten, and salvable dead trees 12.5 centimeters and larger in d.b.h., from stump to a minimum 10-centimeter diameter outside bark. The minimum length of any section included is one meter.

Basal area—The area in square meters of the cross section at breast height of a single tree or of all the trees in a stand, expressed as square meters per hectare.

D.b.h. (diameter at breast height)—Tree diameter in centimeters, outside bark, measured at 1.3 meters above ground.

SPECIES LIST

Tree species tallied in the Toro Negro survey, 1983[1]

Code number	Scientific name	Common name
1	*Cyathea arborea* (L.) J.E. Smith	Helecho gigante
7	*Prestoea montana* (R. Grah.) Nichols.	Palma de sierra
12	*Piper aduncum* L.	Higuillo
16	*Trema micrantha* (L.) Blume	Guacimilla
20	*Cecropia peltata* L.	Yagrumo hembra
22	*Ficus citrifolia* Mill.	Jaguey blanco
24	*Ficus perforata* L.	Jaguey colorado
27	*Coccoloba swartzii* Meisn.	Ortegon
32	*Pisonia subcordata* Sw.	Corcho blanco
33	*Guapira fragrans* (Dum.-Cours.) Little	Corcho
34	*Magnolia portoricensis* Bello	Jaguilla

ree species tallied in the Toro Negro survey, 1983[1]—(Continued)

de number	Scientific name	Common name
37	*Annona muricata* L.	Guanabana
48	*Ocotea leucoxylon* (Sw.) Mez	Laurel geo
51	*Persea americana* Mill.	Aguacate
55	*Brunellia comocladifolia* Humb. & Bonpl.	Palo bobo
56	*Weinmannia pinnata* L.	Oreganillo
62	*Inga fagifolia* (L.) Willd.	Guama
63	*Inga quaternata* Poepp. & Endl.	Guama venezolano
64	*Inga vera* Willd.	Guaba
81	*Andira inermis* (W. Wright) DC.	Moca
84	*Erythrina poeppigiana* (Walp.) O.F. Cook	Bucayo gigante
86	*Lonchocarpus pentaphyllus* (Poir.) DC.	Retama
87	*Ormosia krugii* Urban	Palo de matos
100	*Citrus sinensis* Osbeck	China
102	*Zanthoxylum martinicense* (Lam.)	Espino rubial
106	*Dacryodes excelsea* Vahl	Tabonuco
107	*Tetragastris balsamifera* (Sw.) Oken.	Masa
108	*Cedrela odorata* L.	Cedro hembra
109	*Guarea guidonia* (L.) Sleumer	Guaraguao
111	*Swietenia macrophylla* King	Caoba hondurena
114	*Trichilia pallida* Sw.	Gaeta
115	*Byrsonima coriacea* (Sw.) DC	Maricao
116	*Byrsonima crassifolia* (L.) H.B.K.	Maricao cimarron
118	*Alchornea latifolia* Sw.	Achiotillo
119	*Alchorneopsis portoricensis* Urban	Palo de gallina
121	*Drypetes glauca* Vahl	Varital
129	*Sapium laurocerasus* Desf.	Tabaiba
131	*Mangifera indica* L.	Mango
133	*Spondias dulcis* Parkinson	Jobo de la India
136	*Cyrilla racemiflora* L.	Palo colorado
139	*Matayba domingensis* (D.C.) Radlk.	Negra lora
141	*Sapindus saponaria* L.	Jaboncillo
143	*Thouinia striata* Radlk.	Ceboruquillo
144	*Meliosma herbertii* Rolfe	Aguacatillo
149	*Sloanea berteriana* Choisy	Motillo
150	*Hibiscus tiliaceus* L.	Emajagua
151	*Montezuma speciossima* Sesse & Moc.	Maga
156	*Guazuma ulmifolia* Lam.	Guacima
161	*Calophyllum calaba* L.	Maria
162	*Clusia grisebachiana* (Planch. & Triana) Alain.	Cupeillo
169	*Casearia arborea* (L. C. Rich) Urban	Rabo raton
170	*Casearia decandra* Jacq.	Tostado
171	*Casearia guianensis* (Aubl.) Urban	Palo blanco
172	*Casearia sylvestris* Sw.	Cafeillo
173	*Homalium racemosum* Jacq.	Caracolillo
177	*Daphnopsis philippiana* Krug & Urban.	Majagua brava
180	*Buchenavia capitata* (Vahl) Eichl.	Granadillo
185	*Calyptranthes krugii* Kiaersk	Limoncillo
186	*Eucalyptus robusta* J. E. Smith	Eucalypto
187	*Eugenia domingensis* Berg.	Guasabara
188	*Eugenia jambos* L.	Pomarrosa
190	*Eugenia rhombea* (Berg) Krug & Urban	Hoja menuda
191	*Eugenia stahlii* (Kiaersk.) Krug & Urban	Guayabota
192	*Myrcia deflexa* (Poir.) DC	Cieneguillo

Tree species tallied in the Toro Negro survey, 1983[1]—(Continued)

Code number	Scientific name	Common name
193	*Myrcia splendens* (Sw.) DC	Hoja menuda
196	*Calycogonium squamulosum* Cogn.	Jusillo
197	*Heterotrichum cymosum* (Wendl.) Urban	Camasey peludo
198	*Miconia prasina* (Sw.) DC	Camasey
200	*Dendropanax arboreus* (L.) Decne. & Planch.	Pollo
201	*Didymopanax morototoni* (Aubl.) Decne. & Planch.	Yagrumo macho
203	*Rapanea coriacea* (Sw.) Mez.	Mantequero
204	*Rapanea guianensis* Aubl.	Badula
205	*Chrysophyllum argenteum* Jacq.	Lechecillo
211	*Micropholis chrysophylloides* Pierre	Caimitillo
213	*Pouteria multiflora* (A. DC.) Eyma	Jacana
215	*Symplocos martinicensis* Jacq.	Aceituna blanca
221	*Cordia alliodora* (Ruiz & Pav.) Oken	Capa prieto
224	*Cordia sulcata* DC.	Moral
230	*Vitex divaricata* Sw.	Higuerillo
231	*Solanum rugosum* Dunal	Tabacon
236	*Tabebuia heterophylla* (DC.) Britton	Roble blanco
240	*Coffea arabica* L.	Cafe
242	*Faramea occidentalis* (L.) A Rich.	Cafeillo
244	*Guettarda scabra* (L.) Vent.	Palo de cucubano
245	*Ixora ferrea* (Jacq.) Benth.	Cafeillo
248	*Rondeletia portoricensis* Krug. & Urban.	Juan Tomas
251	*Cyathea aquilina* (Christ) Domin	Helecho gigante
252	*Cyathea tenera* (J. E. Sm.) Moore	Helecho gigante
255	*Nephelea portoricensis* (Spreng.) Tryon	Helecho gigante espinosa
256	*Alsophila bryophila* Tryon	Helecho gigante de la sierra
279	*Piper amalago* L.	Higuillo de limon
280	*Piper blattarum* Spreng.	Higuillo
298	*Trophis racemosa* (L.) Urban	Ramon
313	*Coccoloba sintenisii* Urban	Uvero de monte
330	*Nectandra antillana* Meisn.	Aguacatillo
332	*Nectandra membranacea* (Sw.) Griseb.	Laurel prieto
333	*Nectandra patens* (Sw.) Griseb.	Laurel geo colorado
341	*Phoebe montana* (Sw.) Griseb.	Avispillo
364	*Inga fastuosa* (Jacq.) Willd.	Guaba venezolana
413	*Guarea rameflora* Vent.	Guaraguadillo
485	*Meliosma obtusifolia* (Bello) Krug & Urban	Arroyo
489	*Rhamnus sphaerosperma* Sw.	West Indian buckthorn
518	*Clusia minor* L.	Cupey de monte
523	*Banana portoricensis* Krug & Urban	Palo de ramon
540	*Daphnopsis americana* (Mill.) J. R. Johnst.	Majagua de sierra
548	*Cassipourea guianensis* Aubl.	Palo de gongoli
549	*Myrcia citrifolia* (Aubl.) Urban	Limoncillo del monte
550	*Myrcia leptoclada* DC.	Guayabacon
554	*Calyptranthes pallens* Griseb.	Tapon blanco
560	*Eucalyptus resinifera* J.E. Smith	Eucalipto
568	*Eugenia eggersii* Kiaersk.	Guasabara
578	*Eugenia sintenisii* Kiaersk.	Murta
579	*Eugenia stewardsonii* Britton	
585	*Myrcia fallax* (A. Rich.) DC.	Hoja menuda
586	*Myrcia paganii* Krug & Urban	
592	*Clidemia umbrosa* (Sw.) Cogn.	
598	*Mecranium amygdalinum* (Desr.) C. Wright	Camasey almendro

Tree species tallied in the Toro Negro survey, 1983[1]—(Continued)

Code number	Scientific name	Common name
600	*Miconia foveolata* Cogn.	Camasey
601	*Miconia impetiolaris* (Sw.) D. Don	Camasey de costilla
602	*Miconia laevigata* (L.) DC.	Camasey de paloma
603	*Miconia mirabilis* (Aubl.) L.O. Wms.	Camasey cuatrocanales
605	*Miconia pachyphylla* Cogn.	Camasey racimoso
608	*Miconia racemosa* (Aubl.) DC.	Camasey felpa
610	*Miconia serrulata* (DC.) Naud.	Camasey
611	*Miconia sintenisii* Cogn.	Camasey
612	*Miconia subcorymbosa* Britton	Camasey
617	*Ossaea krugiana* Cogn.	
619	*Tetrazygia biflora* (Cogn.) Urban	Camasey
620	*Tetrazygia stahlii* Cogn.	Camasey
621	*Tetrazygia urbanii* Cogn.	Camasey
624	*Dendropanax laurifolius* (E. March.) R. C. Schneid.	Gongoli
625	*Didymopanax gleasonii* Britton & Wils	Yuquilla
635	*Wallenia pendula* (Urban) Mez	Jacanillo
657	*Haenianthus salicifolius* Griseb.	Palo de hueso
687	*Brunfelsia americana* L.	Aguacero
692	*Cestrum macrophyllum* Vent.	Galan del monte
709	*Tabebuia schumanniana* Urban	Roble colorado
727	*Guettarda ovalifolia* Urban	Cucubano
738	*Palicourea riparia* Benth.	Cachimbo
741	*Psychotria berteriana* DC.	Cachimbo comun

[1]Species and codes as listed in Little and Wadsworth (1964) and Little et. al. (1974).

Unit Conversion Factors

Metric to English and English to Metric Conversions

1 cm. = 0.3937 in.	1 in. = 2.54 cm.
1 m. = 3.281 ft.	1 ft. = .3048 in.
1 km. = .6214 mi.	1 mi. = 1.6093 km.
1 sq.m. = 10.7639 sq.ft.	1 sq.ft. = 0.0929 sq.m.
1 sq.km. = 0.3861 sq.mi.	1 sq.mi. = 2.59 sq.km.
1 ha. = 2.471 ac.	1 ac. = 0.4047 ha.
1 cu.m. = 35.3145 cu.ft.	1 cu.ft. = 0.0283 cu.m.
1 sq.m./ha. = 4.356 sq.ft./ac.	1 sq.ft./ac. = 0.2296 sq.m./ha.
1 cu.m./ha. = 14.29 cu.ft./ac.	1 cu.ft./ac. = 0.07 cu.m./ha.

Metric Inventory Standards

Item	Metric standard
Prism size	BAF 2.5
Grid spacing	3 km.
Cluster point spacing	25 m.
Fixed plot size	40 $m.^2$(r = 3.6 m.)
	15 $m.^2$(r = 2.2 m.)
Breast height	1.3 m.
Stump height	30 cm.
Diameter classes	5 cm. = 2.5 to 7.5 cm. d.b.h.
	10 cm. = 7.5 to 12.5 cm. d.b.h.
	15 cm. = 12.5 to 17.5 cm. d.b.h.
	20 cm. = 17.5 to 22.5 cm. d.b.h. etc.
Tree size classes	
Sapling	2.5 to 12.5 cm. d.b.h.
Poletimber (hardwood)	12.5 to 27.5 cm. d.b.h.
Sawtimber (hardwood)	27.5 cm. + d.b.h.
Sawtimber (softwood)	22.5 cm. + d.b.h.
Minimum top D.O.B	
Cubic volume	10 cm.
Hardwood sawlog	22.5 cm.
Softwood sawlog	17.5 cm.
Sapling	2.5 cm.
Minimum D.I.B. sawlog	
Hardwood	20 cm.
Softwood	15 cm.
Minimum length	
Cubic section	1 m.
Sawlog	2.5 m.
Sawtimber tree	3.5 m. sawlog

Tables

Page

Forest characteristics

1.—Physiographic characteristics by forest class, Toro Negro public forest, 1983 16
2.—Physiographic characteristics of private timberland by forest class, Toro Negro region, 1983 16
3.—Forest characteristics by forest class, Toro Negro public forest, 1983 16
4.—Forest characteristics of private timberland by forest class, Toro Negro region, 1983 17
5.—Average number of live trees by diameter class and forest class, Toro Negro region, 1983 17

Area tables

6.—Area by land class and owner, Toro Negro region, 1983 17
7.—Forest area by forest class and division, Toro Negro public forest, 1983 18
8.—Forest area by forest class and life zone, Toro Negro public forest, 1983 18
9.—Private timberland area by forest class and life zone, Toro Negro region, 1983 18
10.—Forest area by forest class and past disturbance, Toro Negro public forest, 1983 18

Species composition tables

11.—Number of live trees by species and diameter class, ranked by basal area plurality, Toro Negro public plantations, 1983 19
12.—Number of live trees by species and diameter class, ranked by basal area plurality, Toro Negro other public timberland, 1983 19
13.—Number of live trees by species and diameter class, ranked by basal area plurality, Toro Negro public upper mountain forest, 1983 20
14.—Number of live trees by species and diameter class, ranked by basal area plurality, Toro Negro public palm forest, 1983 20
15.—Number of live trees by species and diameter class, ranked by basal area plurality, Toro Negro public dwarf forest, 1983 21
16.—Number of live trees by species and diameter class, ranked by basal area plurality, Toro Negro private timberland, 1983 21
17.—Dominant seedlings on public and private forests by forest class and species, Toro Negro region, 1983 22

Volume tables

18.—Volume of timber, growing stock, and sawtimber by species and tree size class, Toro Negro public plantations, 1983 22
19.—Volume of timber, growing stock, and sawtimber by species and tree size class, Toro Negro other public timberland, 1983 23
20.—Volume of timber, growing stock, and sawtimber by species and tree size class, Toro Negro private timberland, 1983 24
21.—Volume of timber by use category and forest class, Toro Negro region, 1983 24
22.—Volume of timber by class of timber and forest class, Toro Negro region, 1983 25

Management tables

23.—Average number of trees by tree class, species, and size class, ranked by basal area plurality, Toro Negro public plantations, 1983 26
24.—Average number of trees by tree class, species, and size class, ranked by basal area plurality, Toro Negro other public timberland, 1983 27
25.—Average number of trees by tree class, species, and size class, ranked by basal area plurality, Toro Negro private timberland, 1983 28
26.—Basal area by size class, tree class, and forest class, Toro Negro region 1983 29

Table 1.—*Physiographic characteristics by forest class, Toro Negro public forest, 1983*

Characteristic (units)	Statistic	Forest class					All classes
		Plantations	Other timberland	Upper mountain	Palm	Dwarf	
Elevation	Mean:	830	820	1010	980	1150	920
(meters)	Range:	730–890	710–950	900–1200	780–1200	1050–1250	710–1250
Rainfall[1]	Mean:	2500	2450	2560	2570	2670	2520
(millimeters)	Range:	2400–2600	2300–2600	2400–2800	2300–2900	2300–2800	2300–2900
Slope[2]	Mean:	40	50	70	55	70	55
(percent)	Range :	20–50	20–70	60–80	30–70	70–80	20–80
Distance to road	Mean:	320	280	770	720	670	520
(meters)	Range:	100–600	0–800	200–1600	0–1800	100–1100	0–1800
Distance to water	Mean:	290	300	380	310	330	320
(meters)	Range:	40–460	20–740	80–830	10–760	120–680	10–830

[1]Mean annual precipitation from isohyet map (Commonwealth of Puerto Rico 1979).
[2]Average slope at each plot location.

Table 2.—*Physiographic characteristics of private timberland by forest class, Toro Negro region, 1983*

Characteristic (units)	Statistic	Forest class			All classes
		Secondary forest	Abandoned coffee shade	Active coffee shade	
Elevation	Mean:	750	790	470	710
(meters)	Range:	380–960	630–1000	350–590	350–1000
Rainfall[1]	Mean:	2220	2180	2230	2210
(millimeters)	Range:	1800–2700	1600–2400	2100–2300	1600–2700
Slope[2]	Mean:	50	55	60	50
(percent)	Range:	20–90	20–80	20–80	20–90

[1]Mean annual precipitation from isohyet map (Commonwealth of Puerto Rico 1979).
[2]Average slope at each plot location.

Table 3.—*Forest characteristics by forest class, Toro Negro public forest, 1983*

Characteristic (units)	Statistic	Forest class					All classes
		Plantations	Other timberland	Upper mountain	Palm	Dwarf	
Basal area[1]	Mean:	29.5	26.1	31.8	34.5	20.6	29.3
(m^2/ha)	Range:	24.1–36.6	14.0–35.9	26.2–42.9	23.9–42.4	12.1–31.0	12.1–42.9
Number of trees[1]	Mean:	2039	2907	2926	2206	2869	2601
(stems/ha)	Range:	1077–2878	1549–4775	2102–4406	1457–3506	2650–3136	1077–4775
Mean diameter[2]	Mean:	14.2	10.8	12.1	14.1	9.4	12.3
(centimeters)	Range:	11.7–18.6	7.7–13.6	9.3–14.3	11.0–17.4	7.0–11.8	7.0–18.6
Mean canopy height[3]	Mean:	22.2	13.5	10.4	11.1	6.7	12.8
(meters)	Range:	15.7–26.8	8.5–18.4	8.0–13.5	8.6–14.7	5.6–7.9	5.6–26.8
Total volume[4]	Mean:	321.4	174.9	176.2	200.1	73.9	192.3
(m^3/ha)	Range:	238.8–423.8	66.6–311.4	85.9–296.7	113.8–279.1	47.6–114.1	47.6–423.8
Timber volume[5]	Mean:	184.5	124.6				137.7
(m^3/ha)	Range:	160.0–213.2	50.2–245.9	.....	.....	.....	50.2–245.9

[1]All trees 2.5 cm. d.b.h. and larger.
[2]Quadratic mean at each plot location.
[3]Based on dominant and codominant trees.
[4]Total overbark volume of trees 12.5 cm. and larger using equation by Dawkins (1961).
[5]All sound wood of trees 12.5 cm. and larger, from stump to a 10 cm. minimum diameter.

Table 4.—*Forest characteristics of private timberland by forest class, Toro Negro region, 1983*

Characteristic (units)	Statistic	Forest class			All classes
		Secondary forest	Abandoned coffee shade	Active coffee shade	
Basal area[1]	Mean:	13.5	17.6	7.8	13.5
(m^2/ha)	Range:	0.9–27.8	13.0–21.1	3.8–14.3	0.9–27.8
Number of trees[1]	Mean:	1672	2383	1840	1869
(stems/ha)	Range:	16–5146	924–4596	697–2525	16–5146
Mean diameter[2]	Mean:	10.8	11.2	7.4	10.3
(centimeters)	Range:	4.8–17.4	6.0–15.9	5.4–8.5	4.8–17.4
Mean canopy height[3]	Mean:	12.0	15.0	12.2	12.7
(meters)	Range:	6.0–17.2	7.9–23.7	12.1–12.5	6.0–23.7
Total volume[4]	Mean:	95.1	127.6	52.7	95.3
(m^3/ha)	Range:	0–245.9	27.9–167.6	21.8–111.0	0–245.9
Timber volume[5]	Mean:	54.9	80.4	22.5	58.4
(m^3/ha)	Range:	0–240.7	17.7–115.9	6.8–43.4	0–240.7

[1]All trees 2.5 cm. d.b.h. and larger.
[2]Quadratic mean at each plot location.
[3]Based on dominant and codominant trees.
[4]Total overbark volume of trees 12.5 cm. and larger using equation by Dawkins (1961).
[5]All sound wood of trees 12.5 cm. and larger, from stump to a 10 cm. minimum diameter.

Table 5.—*Average number of live trees by diameter class and forest class, Toro Negro region, 1983*[1]

Diameter class (cm.)	Public forest class					Private timberland
	Plantations	Other timberland	Upper mountain	Palm	Dwarf	
	trees per hectare					
5	1,405	1,963	1,400	722	1,747	1,479
10	245	414	698	533	491	173
15	124	206	434	287	401	66
20	73	177	238	500	180	68
25	44	74	93	130	37	35
30	44	37	40	19	12	22
35	32	16	11	7	0	10
40	31	10	9	4	0	8
45	12	5	2	2	0	4
50	8	2	0	0	0	1
55	7	1	1	0	0	1
60	8	1	1	0	0	0
65 and greater	5	1	0	0	0	1
Total	2,039	2,907	2,926	2,206	2,869	1,869

[1]Totals may not add due to rounding.

Table 6.—*Area by land class and owner, Toro Negro region,*[1] *1983*

Land class	Owner class				All owners	
	Public		Private			
	cuerdas[2]	*hectares*	*cuerdas*	*hectares*	*cuerdas*	*hectares*
Timberland	2,603	1,024	48,542	19,111	51,145	20,135
Other forest land	3,854	1,518	2,080	819	5,934	2,337
Nonforest land	181	71	36,061	14,197	36,242	14,268
Total land	6,638	2,613	86,683	34,127	93,321	36,740

[1]Includes the area within 2 USGS 7.5 minute quadrangles: Orocovis and Jayuya.
[2]Local unit of measure. One cuerda=0.3937 hectare.

Table 7.—*Forest area by forest class and division, Toro Negro public forest, 1983*

Forest class	Public forest division			Total public
	El Guineo	Doña Juana	Matrullas	
	hectares			
Timberland				
Plantations	0	101	50	151
Other timberland[1]	423	205	245	873
Total	423	306	295	1,024
Other forest				
Upper mountain	221	4	0	225
Palm	652	99	53	804
Dwarf	489	0	0	489
Total	1,362	103	53	1,518
All forest land	1,785	409	348	2,542

[1]Includes abandoned coffee shade and other successional forest types.

Table 8.—*Forest area by forest class and life zone[1], Toro Negro public forest, 1983*

Forest class	Life zone		Life zones
	Subtropical wet forest	Lower montane wet forest	
	hectares		
Plantations	151	0	151
Other timberland[2]	450	0	450
Upper mountain	4	221	225
Palm	152	652	804
Dwarf	0	489	489
Total	757	1,362	2,119

[1]Life zones defined by Holdridge (1967).
[2]Excluding 423 hectares of timberland in El Guineo division.

Table 9.—*Private timberland area by forest class and life zone[1], Toro Negro region, 1983*

Forest class	Life zone			All life zones
	Subtropical moist forest	Subtropical wet forest	Lower montane wet forest	
	hectares			
Secondary forest	2,248	6,746	2,248	11,242
Abandoned coffee shade	0	3,373	1,124	4,497
Active coffee shade	1,124	2,248	0	3,372
Total	3,372	12,367	3,372	19,111

[1]Life zones defined by Holdridge (1967).

Table 10.—*Forest area by forest class and past disturbance[1], Toro Negro public forest, 1983*

Forest class	Past land use				
	Coffee shade	Pasture	Brush	Forest	Total
	hectares				
Plantations	50	0	34	67	151
Other timberland[2]	110	90	54	196	450
Upper mountain	0	0	0	225	225
Palm	26	0	0	778	804
Dwarf	0	0	0	489	489
Total	186	90	88	1,755	2,119

[1]From historical land use map (Gulick 1951).
[2]Excluding 423 hectares of timberland in El Guineo division.

Table 11.—*Number of live trees by species and diameter class, ranked by basal area plurality, Toro Negro public plantations, 1983*[1]

Species code	Scientific name	Total basal area (square meters)	Tree size class[2]			All classes
			Sapling	Poletimber	Sawtimber	
			thousand trees			
186	*Eucalyptus robusta*	2,810	3	8	18	29
211	*Micropholis chrysophylloides*	169	3	8	0	11
64	*Inga vera*	118	5	3	*	8
109	*Guarea guidonia*	112	0	3	1	3
20	*Cecropia peltata*	111	0	2	1	2
255	*Nephelea portoricensis*	105	14	0	0	14
188	*Eugenia jambos*	83	26	1	0	27
236	*Tabebuia heterophylla*	73	10	2	0	12
118	*Alchornea latifolia*	69	8	2	0	10
7	*Prestoea montana*	67	3	1	0	4
201	*Didymopanax morototoni*	62	0	2	*	2
62	*Inga fagifolia*	49	0	1	*	1
180	*Buchenavia capitata*	49	0	0	*	*
129	*Sapium laurocerasus*	48	6	0	*	6
	Other species (33)	534	172	4	1	177
	All species	4,460	249	36	23	308

[1]Totals may not add due to rounding.
[2]Saplings are 2.5 to 12.5 cm. d.b.h.; poletimber trees are 12.5 to 27.5 cm. d.b.h.; sawtimber trees are larger than 27.5 cm. d.b.h.
*Less than 500 trees.

Table 12.—*Number of live trees by species and diameter class, ranked by basal area plurality, Toro Negro other public timberland*[1]*, 1983*[2]

Species code	Scientific name	Total basal area (square meters)	Tree size class[3]			All classes
			Sapling	Poletimber	Sawtimber	
			thousand trees			
7	*Prestoea montana*	1,245	4	44	0	48
20	*Cecropia peltata*	1,091	5	20	5	30
188	*Eugenia jambos*	834	133	13	4	150
109	*Guarea guidonia*	758	25	9	5	38
62	*Inga fagifolia*	735	42	14	2	58
211	*Micropholis chrysophylloides*	688	43	9	3	55
169	*Casearia arborea*	622	93	14	1	108
255	*Nephelea portoricensis*	580	109	0	0	109
180	*Buchenavia capitata*	400	0	0	2	2
224	*Cordia sulcata*	392	7	12	*	19
236	*Tabebuia heterophylla*	389	11	14	0	25
118	*Alchornea latifolia*	375	21	7	1	29
186	*Eucalyptus robusta*	293	0	0	2	2
111	*Swietenia macrophylla*	293	0	3	2	5
162	*Clusia grisebachiana*	204	0	7	0	7
64	*Inga vera*	172	12	2	1	14
106	*Dacryodes excelsea*	150	0	*	1	1
201	*Didymopanax morototoni*	148	7	4	*	11
87	*Ormosia krugii*	140	2	1	1	4
149	*Sloanea berteriana*	136	1	1	1	2
150	*Hibiscus tiliaceus*	121	53	0	0	53
192	*Myrcia deflexa*	113	31	3	0	34
173	*Homalium racemosum*	112	16	3	0	19
	Other species (50)	1,750	456	26	3	485
	All species	11,739	1,070	205	33	1,308

[1]Excluding 423 hectares of timberland in El Guineo division.
[2]Totals may not add due to rounding.
[3]Saplings are 2.5 to 12.5 cm. d.b.h.; poletimber trees are 12.5 to 27.5 cm. d.b.h.; sawtimber trees are larger than 27.5 cm. d.b.h.
*Less than 500 trees.

Table 13.—*Number of live trees by species and diameter class, ranked by basal area plurality, Toro Negro public upper mountain forest, 1983*[1]

Species code	Scientific name	Total basal area (square meters)	Tree size class[2]			All classes
			Sapling	Poletimber	Sawtimber	
			thousand trees			
7	*Prestoea montana*	1,999	6	78	0	84
211	*Micropholis chrysophylloides*	1,067	46	22	3	71
20	*Cecropia peltata*	593	*	7	4	11
619	*Tetrazygia biflora*	519	12	10	2	25
255	*Nephelea portoricensis*	342	57	2	0	59
139	*Matayba domingensis*	299	39	3	0	42
1	*Cyathea arborea*	269	30	5	0	35
196	*Calycogonium squamulosum*	242	24	4	*	29
162	*Clusia grisebachiana*	215	0	6	0	6
62	*Inga fagifolia*	194	0	3	1	4
136	*Cyrilla racemiflora*	187	3	7	1	11
169	*Casearia arborea*	140	15	5	0	20
248	*Rondeletia portoricensis*	126	12	2	0	14
64	*Inga vera*	125	3	1	1	5
709	*Tabebuia schumanniana*	94	3	2	*	5
118	*Alchornea latifolia*	94	3	4	*	8
121	*Drypetes glauca*	84	45	2	0	47
	Other species (25)	571	173	9	*	182
	All species	7,158	472	172	14	658

[1]Totals may not add due to rounding.
[2]Saplings are 2.5 to 12.5 cm. d.b.h.; poletimber trees are 12.5 to 27.5 cm. d.b.h.; sawtimber trees are larger than 27.5 cm. d.b.h.
*Less than 500 trees.

Table 14.—*Number of live trees by species and diameter class, ranked by basal area plurality, Toro Negro public palm forest, 1983*[1]

Species code	Scientific name	Total basal area (square meters)	Tree size class[2]			All classes
			Sapling	Poletimber	Sawtimber	
			thousand trees			
7	*Prestoea montana*	16,530	33	535	3	571
1	*Cyathea arborea*	2,196	134	53	1	187
211	*Micropholis chrysophylloides*	1,989	99	40	7	146
20	*Cecropia peltata*	1,157	15	19	5	39
248	*Rondeletia portoricensis*	1,086	60	21	2	83
62	*Inga fagifolia*	632	5	7	3	16
196	*Calycogonium squamulosum*	529	56	13	0	69
139	*Matayba domingensis*	301	9	11	1	22
129	*Sapium laurocerasus*	299	0	2	2	5
255	*Nephelea portoricensis*	267	49	0	0	49
	Other species (25)	2,771	549	36	3	587
	All species	27,757	1,010	737	27	1,774

[1]Totals may not add due to rounding.
[2]Saplings are 2.5 to 12.5 cm. d.b.h.; poletimber trees are 12.5 to 27.5 cm. d.b.h.; sawtimber trees are larger than 27.5 cm. d.b.h.

Table 15.—*Number of live trees by species and diameter class, ranked by basal area plurality, Toro Negro public dwarf forest, 1983*[1]

Species code	Scientific name	Total basal area (square meters)	Tree size class[2]			All classes
			Sapling	Poletimber	Sawtimber	
			thousand trees			
1	*Cyathea arborea*	2,034	187	36	0	223
162	*Clusia grisebachiana*	1,392	67	51	0	117
7	*Prestoea montana*	1,223	0	49	0	49
196	*Calycogonium squamulosum*	1,045	53	35	4	92
251	*Cyathea aquilina*	997	80	34	0	114
139	*Matayba domingensis*	697	27	25	0	52
255	*Nephelea portoricensis*	407	107	6	0	113
185	*Calyptranthes krugii*	353	40	18	0	58
136	*Cyrilla racemiflora*	310	40	18	0	58
709	*Tabebuia schumanniana*	270	27	11	0	37
48	*Ocotea leucoxylon*	234	27	11	0	38
625	*Didymopanax gleasonii*	188	67	0	0	67
20	*Cecropia peltata*	136	0	0	2	2
203	*Rapanea coriacea*	136	0	8	0	8
144	*Meliosma herbertii*	117	40	0	0	40
489	*Rhamnus sphaerosperma*	116	40	0	0	40
187	*Eugenia domingensis*	113	40	0	0	40
	Other species (9)	288	254	0	0	254
	All species	10,054	1,095	302	6	1,403

[1]Totals may not add due to rounding.
[2]Saplings are 2.5 to 12.5 cm. d.b.h.; poletimber trees are 12.5 to 27.5 cm. d.b.h.; sawtimber trees are larger than 27.5 cm d.b.h.

Table 16.—*Number of live trees by species and diameter class, ranked by basal area plurality, Toro Negro private timberland, 1983*[1]

Species code	Scientific name	Total basal area (square meters)	Tree size class[2]			All classes
			Sapling	Poletimber	Sawtimber	
			thousand trees			
109	*Guarea guidonia*	28,671	2,946	178	135	3,258
64	*Inga vera*	28,091	736	286	165	1,188
7	*Prestoea montana*	21,545	0	682	14	696
20	*Cecropia peltata*	17,376	460	57	133	650
188	*Eugenia jambos*	15,221	3,867	110	22	3,999
200	*Dendropanax arboreus*	12,975	829	126	69	1,023
81	*Andira inermis*	9,642	276	252	12	540
118	*Alchornea latifolia*	9,145	184	205	29	418
62	*Inga fagifolia*	7,640	92	17	65	174
240	*Coffea arabica*	6,754	7,181	0	0	7,181
84	*Erythrina poeppigiana*	6,557	0	60	14	75
151	*Montezuma speciossima*	6,557	0	95	33	128
133	*Spondias dulcis*	5,704	92	105	19	216
32	*Pisonia subcordata*	5,115	184	58	20	261
131	*Mangifera indica*	5,038	92	0	19	111
172	*Casearia sylvestris*	4,719	3,959	0	0	3,959
224	*Cordia sulcata*	4,055	276	101	0	377
51	*Persea americana*	3,747	0	71	25	95
100	*Citrus sinensis*	3,745	552	96	0	649
251	*Cyathea aquilina*	3,386	460	0	0	460
203	*Rapanea coriacea*	3,220	921	46	0	967
221	*Cordia alliodora*	2,994	184	18	21	223
24	*Ficus perforata*	2,810	0	48	3	52
16	*Trema micrantha*	2,655	92	31	15	138
255	*Nephelea portoricensis*	2,640	92	118	0	210
107	*Tetragastris balsamifera*	2,603	368	53	0	421
	Other species (43)	34,931	7,733	432	80	8,244
	All species	257,540	31,576	3,245	892	35,713

[1]Totals may not add due to rounding.
[2]Saplings are 2.5 to 12.5 cm. d.b.h.; poletimber trees are 12.5 to 27.5 cm. d.b.h.; sawtimber trees are larger than 27.5 cm d.b.h.

Table 17.—*Dominant seedlings on public and private forests by forest class and species, Toro Negro region, 1983*

Species code	Scientific name	Public forest class					Private forests
		Plantations	Other timberland	Upper mountain	Palm	Dwarf	
		percent[1]					
7	*Prestoea montana*	20	4	3	23	4	2
62	*Inga fagifolia*	0	4	4	3	0	0
63	*Inga quaternata*	0	0	0	0	0	5
109	*Guarea guidonia*	0	0	0	0	0	5
121	*Drypetes glauca*	8	0	1	0	0	3
169	*Casearia arborea*	3	6	0	1	0	0
172	*Casearia sylvestris*	5	2	0	3	0	8
177	*Daphnopsis philippiana*	0	3	22	15	0	2
188	*Eugenia jambos*	8	11	1	0	0	0
191	*Eugenia stahlii*	3	4	6	0	0	1
192	*Myrcia deflexa*	1	8	3	3	19	4
193	*Myrcia splendens*	0	0	0	0	0	4
196	*Calycogonium squamulosum*	0	0	4	6	4	0
211	*Micropholis chrysophylloides*	0	3	3	7	0	2
240	*Coffea arabica*	0	11	1	1	0	32
255	*Nephelea portoricensis*	5	3	1	1	4	0
256	*Alsophila bryophila*	1	6	0	1	0	0
413	*Guarea rameflora*	0	3	6	7	0	1
602	*Miconia laevigata*	5	6	5	4	0	2
612	*Miconia subcorymbosa*	0	3	5	2	4	0
	Other species (43)	41	23	35	23	65	29
	All species	100	100	100	100	100	100

[1]Proportion of all seedlings tallied within each class.

Table 18.—*Volume of timber*[1]*, growing stock*[2]*, and sawtimber*[3] *by species and tree size class*[4]*, Toro Negro public plantations, 1983*[5]

Species code	Scientific name	Timber volume			Growing-stock volume			Sawtimber volume Total
		Poletimber	Sawtimber	Total	Poletimber	Sawtimber	Total	
		cubic meters						
186	*Eucalyptus robusta*	1,145	20,756	21,901	1,145	16,578	17,723	7,545
211	*Micropholis chrysophylloides*	841	0	841	605	0	605	0
20	*Cecropia peltata*	251	363	614	244	307	551	125
64	*Inga vera*	358	215	573	312	138	450	54
109	*Guarea guidonia*	205	344	549	205	206	411	51
7	*Prestoea montana*	461	0	461	0	0	0	0
180	*Buchenavia capitata*	0	454	454	0	325	325	126
84	*Erythrina poeppigiana*	0	311	311	0	0	0	0
161	*Calophyllum calaba*	0	287	287	0	162	162	0
62	*Inga fagifolia*	82	195	277	82	67	149	0
188	*Eugenia jambos*	268	0	268	0	0	0	0
	Other species (10)	690	636	1,326	690	471	1,161	169
	All species	4,301	23,561	27,862	3,283	18,254	21,537	8,070

[1]Volume of all sound wood in all live trees to a minimum 10 cm. diameter outside bark.
[2]Volume of sound wood (less sound cull volume) in growing-stock trees of commercial species to a minimum 10 cm. diameter outside bark.
[3]Net volume of the sawlog portion of sawtimber trees of commercial species, calculated according to the International rule.
[4]Poletimber trees are between 12.5 and 27.5 cm. d.b.h., and sawtimber trees are greater than 27.5 cm. d.b.h.
[5]Totals may not add due to rounding.

Table 19.—*Volume of timber[1], growing stock[2], and sawtimber[3] by species and tree size class[4], Toro Negro other public timberland[5], 1983[6]*

Species code	Scientific name	Timber volume			Growing-stock volume			Sawtimber volume
		Poletimber	Sawtimber	Total	Poletimber	Sawtimber	Total	Total
		cubic meters						
7	*Prestoea montana*	11,106	0	11,106	0	0	0	0
20	*Cecropia peltata*	2,469	2,988	5,457	2,336	2,347	4,683	1,028
188	*Eugenia jambos*	2,860	1,722	4,582	0	0	0	0
109	*Guarea guidonia*	1,239	2,954	4,193	1,111	2,314	3,425	935
180	*Buchenavia capitata*	0	3,432	3,432	0	2,418	2,418	785
211	*Micropholis chrysophylloides*	1,127	2,234	3,361	1,025	997	2,022	384
62	*Inga fagifolia*	1,766	1,211	2,977	1,519	789	2,308	330
186	*Eucalyptus robusta*	0	2,089	2,089	0	1,660	1,660	680
111	*Swietenia macrophylla*	530	1,312	1,842	530	968	1,498	406
118	*Alchornea latifolia*	779	987	1,766	767	603	1,370	213
224	*Cordia sulcata*	1,406	239	1,645	1,392	187	1,579	68
169	*Casearia arborea*	948	599	1,547	948	78	1,026	24
236	*Tabebuia heterophylla*	1,385	0	1,385	1,364	0	1,364	0
106	*Dacryodes excelsea*	30	1,174	1,204	30	839	869	286
87	*Ormosia krugii*	296	858	1,154	296	557	853	246
149	*Sloanea berteriana*	84	862	946	84	539	623	233
64	*Inga vera*	275	564	839	233	289	522	49
139	*Matayba domingensis*	394	370	764	394	242	636	100
201	*Didymopanax morototoni*	366	318	684	354	192	546	53
162	*Clusia grisebachiana*	588	0	588	491	0	491	0
242	*Faramea occidentalis*	174	386	560	174	280	454	137
	Other species (23)	2,393	1,534	3,927	1,953	951	2,904	368
	All species	30,215	25,833	56,048	15,001	16,250	31,251	6,325

[1]Volume of all sound wood in all live trees to a minimum 10 cm. diameter outside bark.
[2]Volume of sound wood (less sound cull volume) in growing-stock trees of commercial species to a minimum 10 cm. diameter outside bark.
[3]Net volume of the sawlog portion of sawtimber trees of commercial species, calculated according to the International rule.
[4]Poletimber trees are between 12.5 and 27.5 cm. d.b.h., and sawtimber trees are greater than 27.5 cm. d.b.h.
[5]Excluding 423 hectares of timberland in El Guineo division.
[6]Totals may not add due to rounding.

Table 20.—*Volume of timber[1], growing stock[2], and sawtimber[3] by species and tree size class[4], Toro Negro private timberland, 1983[5]*

Species code	Scientific name	Timber volume			Growing stock volume			Sawtimber volume Total
		Poletimber	Sawtimber	Total	Poletimber	Sawtimber	Total	
		cubic meters						
7	*Prestoea montana*	183,300	13,200	196,600	0	0	0	0
109	*Guarea guidonia*	41,300	97,500	138,800	37,900	83,800	121,600	16,900
20	*Cecropia peltata*	19,900	106,200	126,100	19,900	86,400	106,300	34,700
64	*Inga vera*	45,100	70,000	115,100	37,800	37,000	74,800	14,100
200	*Dendropanax arboreus*	8,200	44,800	53,100	5,600	37,800	43,400	5,700
118	*Alchornea latifolia*	42,800	8,600	51,400	42,600	7,600	50,200	2,000
62	*Inga fagifolia*	7,000	39,300	46,300	6,000	24,900	30,900	7,400
84	*Erythrina poeppigiana*	15,800	24,700	40,600	0	0	0	0
32	*Pisonia subcordata*	12,500	27,100	39,700	12,500	15,300	27,800	3,100
81	*Andira inermis*	27,300	6,200	33,500	25,100	3,400	28,600	500
151	*Montezuma speciossima*	7,600	22,900	30,500	1,600	18,400	20,100	3,200
188	*Eugenia jambos*	13,400	14,200	27,600	0	0	0	0
221	*Cordia alliodora*	5,500	17,700	23,200	5,500	10,600	16,100	3,800
133	*Spondias dulcis*	8,700	12,300	21,100	5,400	400	5,800	1,100
51	*Persea americana*	4,100	13,300	17,400	2,900	8,700	11,600	3,400
131	*Mangifera indica*	0	15,900	15,900	0	0	0	0
224	*Cordia sulcata*	15,400	0	15,400	14,600	0	14,700	0
86	*Lonchocarpus pentaphyllus*	0	12,000	12,000	0	11,900	11,900	5,100
34	*Magnolia portoricensis*	0	11,300	11,300	0	10,400	10,400	1,800
211	*Micropholis chrysophylloides*	1,600	9,600	11,300	0	7,800	7,800	2,800
100	*Citrus sinensis*	11,100	0	11,100	0	0	0	0
	Other species (16)	35,500	42,500	78,000	31,900	28,400	60,400	8,400
	All species	506,300	609,600	1,115,900	249,500	392,900	642,400	114,000

[1]Volume of all sound wood in all live trees to a minimum 10 cm. diameter outside bark.
[2]Volume of sound wood (less sound cull volume) in growing-stock trees of commercial species to a minimum 10 cm. diameter outside bark.
[3]Net volume of the sawlog portion of sawtimber trees of commercial species, calculated according to the International rule.
[4]Poletimber trees are between 12.5 and 27.5 cm. d.b.h., and sawtimber trees are greater than 27.5 cm. d.b.h.
[5]Totals may not add due to rounding.

Table 21.—*Volume of timber by use category[1] and forest class, Toro Negro region, 1983[2]*

Species Use category	Forest class		
	Public plantations	Other public timberland[3]	Private timberland
	cubic meters per hectare		
High quality sawtimber	15.9	40.9	13.0
Utility poletimber and sawtimber	152.9	32.4	22.2
Unusable for timber product	6.4	39.6	16.7
Uncommon species	9.3	11.7	6.5
All timber	184.5	124.6	58.4

[1]Use codes for each species are listed in tables 23, 24, and 25.
[2]Totals may not add due to rounding.
[3]Excluding 423 hectares of timberland in El Guineo division.

Table 22.—*Volume of timber by class of timber and forest class, Toro Negro region, 1983*[1]

Class of timber	Forest class		
	Public plantations	Other public timberland[2]	Private timberland
	cubic meters per hectare		
Growing-stock trees			
Sawtimber trees:			
Sawlog portion	110.2	32.9	13.9
Upper stem	6.7	2.7	2.5
Branches and forks	23.4	10.7	4.1
Sound cull	8.7	5.6	2.8
Timber volume	148.9	51.8	23.4
Poletimber trees:			
Bole volume	20.3	33.3	11.2
Branches and forks	0.0	0.0	0.1
Sound cull	5.6	31.7	2.5
Timber volume	5.8	64.9	13.8
Rough and rotten trees			
Bole volume	5.5	0.5	6.0
Branches and forks	2.3	1.4	1.7
Sound cull	1.9	5.8	13.5
Timber volume	9.7	7.8	21.2
All timber	184.5	124.6	58.4

[1]Totals may not add due to rounding.
[2]Excluding 423 hectares in El Guineo division.

Table 23.—*Average number of trees by tree class, species, and size class, ranked by basal area plurality, Toro Negro public plantations, 1983*[1]

Tree class[2]	Species code	Use code[3]	Scientific name	Tree size class[4]			All size classes
				Sapling	Poletimber	Sawtimber	
				trees per hectare			
Growing stock							
	186	2	*Eucalyptus robusta*	18	56	120	193
	211	1	*Micropholis chrysophylloides*	18	38	0	56
	64	2	*Inga vera*	32	17	2	51
	109	1	*Guarea guidonia*	0	17	3	20
	20	2	*Cecropia peltata*	0	10	4	15
	255	3	*Nephelea portoricensis*	73	0	0	73
	188	3	*Eugenia jambos*	155	4	0	159
	236	1	*Tabebuia heterophylla*	68	10	0	78
	118	2	*Alchornea latifolia*	54	15	0	69
	7	3	*Prestoea montana*	18	10	0	28
	201	2	*Didymopanax morototoni*	0	12	2	15
	62	1	*Inga fagifolia*	0	7	0	7
	180	1	*Buchenavia capitata*	0	0	2	2
	129	3	*Sapium laurocerasus*	36	0	2	39
			Other species	786	25	5	816
			Total growing stock	1,259	221	141	1,620
Rough and rotten trees							
			All species	391	20	7	419
All live trees							
			Total	1,650	241	148	2,039

[1]Totals may not add due to rounding.
[2]Growing-stock trees are currently or prospectively merchantable based on form and soundness, regardless of species.
[3]High quality sawtimber is code 1; utility poletimber and sawtimber is code 2; currently unusable timber is code 3.
[4]Saplings are 2.5 to 12.5 cm. d.b.h.; poletimber trees are 12.5 to 27.5 cm. d.b.h.; sawtimber trees are larger than 27.5 cm. d.b.h.

Table 24.—*Average number of trees by tree class, species, and size class, ranked by basal area plurality, Toro Negro other public timberland*[1], *1983*[2]

Tree class[3]	Species code	Use code[4]	Scientific name	Tree size class[5]			All size classes
				Sapling	Poletimber	Sawtimber	
				trees per hectare			
Growing stock							
	7	3	*Prestoea montana*	8	99	0	107
	20	2	*Cecropia peltata*	12	45	11	67
	188	3	*Eugenia jambos*	271	24	3	298
	109	1	*Guarea guidonia*	54	18	10	83
	62	1	*Inga fagifolia*	75	29	4	109
	211	1	*Micropholis chrysophylloides*	95	21	4	119
	169	3	*Casearia arborea*	178	27	1	205
	255	3	*Nephelea portoricensis*	36	0	0	36
	180	1	*Buchenavia capitata*	0	0	4	5
	224	2	*Cordia sulcata*	15	27	1	43
	236	1	*Tabebuia heterophylla*	25	31	0	56
	118	2	*Alchornea latifolia*	46	15	3	64
	186	2	*Eucalyptus robusta*	0	0	3	4
	111	1	*Swietenia macrophylla*	0	6	5	10
	162	3	*Clusia grisebachiana*	0	14	0	14
	64	2	*Inga vera*	26	3	1	30
	106	1	*Dacryodes excelsea*	0	0	3	3
	201	2	*Didymopanax morototoni*	15	9	1	25
	87	2	*Ormosia krugii*	5	3	2	9
	149	2	*Sloanea berteriana*	2	1	3	6
	150	3	*Hibiscus tiliaceus*	89	0	0	89
	192	2	*Myrcia deflexa*	69	6	0	76
	173	2	*Homalium racemosum*	35	7	0	42
			Other species	787	57	6	849
			Total growing stock	1,842	442	64	2,348
Rough and rotten trees							
			All species	535	15	9	559
All live trees							
			Total	2,377	456	74	2,907

[1]Excluding 423 hectares of timberland in El Guineo division.
[2]Totals may not add due to rounding.
[3]Growing-stock trees are currently or prospectively merchantable based on form and soundness, regardless of species.
[4]High quality sawtimber is code 1; utility poletimber and sawtimber is code 2; currently unusable timber is code 3.
[5]Saplings are 2.5 to 12.5 cm. d.b.h.; poletimber trees are 12.5 to 27.5 cm. d.b.h.; sawtimber trees are larger than 27.5 cm. d.b.h.

Table 25.—*Average number of trees by tree class, species, and size class, ranked by basal area plurality, Toro Negro private timberland, 1983*[1]

Tree class[2]	Species code	Use code[3]	Scientific name	Tree size class[4]			All size classes
				Sapling	Poletimber	Sawtimber	
				trees per hectare			
Growing stock							
	109	1	*Guarea guidonia*	149	6	5	160
	64	2	*Inga vera*	39	10	4	52
	7	3	*Prestoea montana*	0	14	0	14
	20	2	*Cecropia peltata*	24	2	6	33
	188	3	*Eugenia jambos*	43	0	0	43
	200	2	*Dendropanax arboreus*	34	3	1	39
	81	1	*Andira inermis*	14	12	1	27
	118	2	*Alchornea latifolia*	10	9	2	21
	62	1	*Inga fagifolia*	5	1	2	8
	240	3	*Coffea arabica*	39	0	0	39
	84	3	*Erythrina poeppigiana*	0	1	*	1
	151	1	*Montezuma speciossima*	0	0	1	1
	133	3	*Spondias dulcis*	5	6	1	11
	32	2	*Pisonia subcordata*	5	3	1	9
	131	3	*Mangifera indica*	5	0	*	5
	172	3	*Casearia sylvestris*	149	0	0	149
	224	2	*Cordia sulcata*	14	5	0	20
	51	3	*Persea americana*	0	4	1	5
	100	3	*Citrus sinensis*	0	0	0	0
	251	3	*Cyathea aquilina*	0	0	0	0
	203	3	*Rapanea coriacea*	43	2	0	46
	221	1	*Cordia alliodora*	10	1	1	12
	24	3	*Ficus perforata*	0	3	*	3
	16	3	*Trema micrantha*	5	2	1	7
	255	3	*Nephelea portoricensis*	0	0	0	0
	107	1	*Tetragastris balsamifera*	19	0	0	19
			Other species	318	16	4	338
			Total growing stock	930	100	31	1,061
Rough and rotten trees							
			All species	723	70	15	808
All live trees							
			Total	1,652	170	47	1,869

[1]Excluding 423 hectares of timberland in El Guineo division.
[2]Totals may not add due to rounding.
[3]High quality sawtimber is code 1; utility poletimber and sawtimber is code 2; currently unusable timber is code 3.
[4]Growing-stock trees are currently or prospectively merchantable based on form and soundness, regardless of species.
*Less than one tree per hectare.

Table 26.—*Basal area by size class, tree class, and forest class, Toro Negro region 1983*[1]

Size class and tree class	Public forest class		All public timberland	All private timberland
	Plantations	Other timberland		
	square meters per hectare			
Saplings:				
Growing stock	3.0	4.2	3.9	2.1
Rough and rotten	.9	1.8	1.5	1.3
Total	3.9	6.0	5.5	3.4
Poletimber trees:				
Growing stock	5.7	12.0	10.5	2.8
Rough and rotten	.7	.5	.5	2.2
Total	6.4	12.5	11.0	5.0
Sawtimber trees:				
Growing stock	18.2	6.7	9.6	3.2
Rough and rotten	.9	.9	.7	1.9
Total	19.1	7.6	10.5	5.1
All growing stock	27.0	22.9	24.0	8.2
All rough and rotten	2.5	3.1	3.0	5.3
All live trees	29.5	26.1	27.0	13.5

[1]Totals may not add due to rounding.

Birdsey, R. A.; Jiménez, D. The forests of Toro Negro. Res. Pap. SO-222. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1985. 29 p.

The Toro Negro region of Puerto Rico is 61 percent forested with 20,100 hectares of timberland and 2,300 hectares of other forest land. *Eucalyptus robusta* accounts for 37 percent of the growing stock volume in the public forest segment. Most eucalyptus plantations in the public forest are ready for harvest and regeneration. Private timberland has adequate sapling stocking which could be released.

Additional keywords: forest inventory, Puerto Rico, timber volume, forest area, tropical forest management.

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Production and Costs of Manual Delimbing, Bucking, and Piling in Thinnings

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SUMMARY

Studies were made of chainsaw delimbing and bucking with manual piling of bunched trees to determine productivity rates and costs for each function. Information was obtained from observations of six thinning operations in the South. Average d.b.h. and bolt length significantly affected total delimbing and bucking time per tree. Manual piling time was dependent on average d.b.h. and stems per bunch.

Production and Costs of Manual Delimbing, Bucking, and Piling in Thinnings

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INTRODUCTION

A large timber base has been established by the extensive planting of southern pines in the South over the past three decades. In the next few years, many of these stands will require thinning to achieve the best economic return. A mixture of methods and equipment is currently being used for thinning, but there is a need for improved machines and systems to reduce harvesting costs associated with thinning.

In the past, thinning systems were labor intensive, with the bobtail truck often serving as the primary means for loading, in-woods forwarding, and hauling. The principal method of felling was the chainsaw. Forwarders (or prehaulers) were added to increase productivity and reduce the seasonal restrictions associated with trucks operating in the woods. Chainsaws were still used to delimb and buck the trees at the stump. The bucked wood was piled manually to increase forwarder productivity (Anon. 1975).

Productivity of forwarders has been increased by including feller-bunchers; these bunch small stems to facilitate delimbing, bucking, and forwarding (Lanford 1982). As with most forwarder systems, the processing functions are completed near the stump with chainsaws. The bucked wood is piled to increase the forwarder's productivity. The manual functions of delimbing, bucking, and piling are critical to the overall productivity of the system. Proper planning and balancing of men and machines are essential for efficient operations.

Productivity rates have been published for delimbing, bucking, and hand piling southern pine that was not bunched by feller-bunchers (Hypes and Stuart 1979). Most of the production and cost information in pine plantations has been for functions following chainsaw felling. Plummer (1977) established some preliminary rates for delimbing and bucking bunched plantation wood when feller-bunchers were used. The purpose of this study was to determine production rates for delimbing, bucking, and piling functions of bunched trees in a feller-buncher and forwarder thinning system.

METHODS

Studies were made of the timing and production of several operating systems during row and selective thinning in loblolly pine plantations. Evaluations were made of five contractor operations in South Carolina, Mississippi, and Louisiana and one company operation in Alabama. After the trees had been felled and bunched in preselected plots, bunches were selected for measurements. Each tree diameter in the bunch was measured at shear level. Two sample trees were selected and d.b.h. and total height were measured in each bunch. Bunch characteristics used in the analysis are shown in table 1. Terrain conditions and tree densities utilized for each stand studied are shown in table 2.

Chainsaw operators were studied while they performed delimbing and bucking. Elemental times and bunch, terrain, and stand characteristics were transferred to computer files for analysis. Piling data was collected in a similar fashion and placed into computer files for analysis.

Delimbing and Bucking

For the delimbing and bucking function, the time per cycle (i.e. bunch) was separated into productive time and delays. Productive time elements are defined in table 3.

Piling

In the South Carolina study, piling of the delimbed and bucked wood was performed by a piler. Partial piling of the top bolts was performed by the chainsaw operators in the three Louisiana studies. The South Carolina study used a product length of 6.5 ft while the Louisiana studies used 7.5 ft.

In the South Carolina study, a piler worked behind the chainsaw operator. He would pile several small bunches that had been delimbed and bucked into one larger pile. The productive pile elements were separated into two basic elements: walk-to-bunch and pile

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Table 1.—*Bunch characteristics*

Element	South Carolina			Mississippi			Louisiana operation 1			Louisiana operation 2			Louisiana operation 3			Alabama		
	Obs.*	Mean	Std. dev.	Obs.	Mean	Std. dev.	Obs.	Mean	Std. dev.	Obs.	Mean	Std. dev.	Obs.	Mean	Std. dev.	Obs.	Mean	Std. dev.
Avg d.b.h., *in*	15	5.9	0.9	74	5.5	1.1	29	6.0	0.5	15	6.9	0.7	22	6.7	0.7	8	6.0	0.7
Total ht, *ft*	15	56.6	6.8	75	34.6	3.2	29	48.7	1.8	15	52.3	2.9	22	51.8	2.7	8	46.3	2.4
Tree vol†, ft^3	15	3.9	1.8	75	2.4	1.5	29	3.6	0.9	15	5.7	1.7	22	5.0	1.4	8	3.6	1.2
Bunch vol†, ft^3	15	17.0	6.7	75	3.8	2.3	29	25.3	6.6	15	36.9	9.9	22	31.4	8.6	8	45.1	9.8
Bunch BA, ft^2	15	0.9	0.3	75	0.3	0.1	29	1.4	0.3	15	1.8	0.7	22	1.6	0.3	8	2.6	0.7
Stems	15	5.0	2.1	75	1.8	0.9	29	7.2	1.4	15	6.5	2.4	22	6.4	1.2	8	13.3	4.1
Bolt length, *ft*		6.5			5.2			7.5			7.5			7.5			7.5	

*Obs. is equal to the number of bunches.
†Inside bark, 4-in o.b. top merchantable limit.

(table 1). In the three Louisiana studies, after delimbing and bucking a bunch, the chainsaw operator would pile the top bolts back onto the lower section of bolts. This increased forwarder productivity and insured that the forwarder did not miss any of the top bolts that might have been hidden by limbs and tops. No piling was done in the Alabama or Mississippi operations.

RESULTS

A summary of the bunch characteristics is shown in table 1. Tree d.b.h. and basal area for all the studies were 5.9 inches and 0.21 ft^2, respectively. Average tree total height was approximately 44 ft. Bunch basal area and volume averaged 1.0 ft^2 and 17.6 ft^3 i.b. (4-in o.b. top merchantable limit). There were approximately five trees per bunch.

Terrain conditions and stand densities are shown in table 2. Slope was measured at each study and was less than 5 percent for all observations. Brush conditions were given coded values of 1 to 4 (light to heavy, respectively) for each study (Lanford and Sirois 1983). The conditions were rated according to visibility. Bogginess was also measured on a scale of 1 to 4 for dry to boggy conditions (Lanford and Sirois 1983).

Scatter diagrams, correlation coefficients, and multiple regression analyses were used to model the elements of the production cycles using the bunch characteristics and terrain conditions as independent variables. Dummy variable techniques were used for the qualitative variables such as brush and bogginess.

Delimbing and Bucking

Productive element times were summarized on a time-per-tree basis. Table 4 shows the statistics for the delimbing and bucking function. The average time to walk to a bunch and completely delimb and buck the stems was 0.72 minutes of productive time per tree.

Delay times for the chainsaw operation included saw refueling and maintenance. The average time was 1.17 minutes per delay, or 0.10 minutes per tree.

Walk-to-Bunch Element.—Variables tested for significance as predictors for walk-to-bunch time were stand conditions (trees/acre, average tree size, crown ratio), bundle size (basal area and number of stems), and terrain conditions (brush, slope, and bogginess). The small amount of variation found in terrain conditions was confounded by other factors because of the range of conditions. The actual distance between bunches was not measured in the study. Since the time to walk between bunches was divided by the number of trees in each bunch, the only significant

Table 2.—*Terrain conditions and stand densities**

Element	South Carolina	Mississippi	Louisiana operation 1	Louisiana operation 2	Louisiana operation 3	Alabama
			mean			
Brush	1†	2	1	3	1	3
Bogginess	2††	1	1	1	1	3
Initial trees/acre	529	501	310	260	290	672
Residual trees/acre	350	232	190	160	200	284
Cut trees/acre	179	269	120	100	90	388

*All sites had slopes less than 5 percent.
†Unobstructed vision as far as terrain allows or at least 132 ft = 1; vision distance less than 132 ft but greater than 66 ft = 2; vision distance less than 66 ft but greater than 33 ft = 3.
††A measure of tractive conditions: firm soil with excellent traction = 1; loose or soft soils with good traction = 2; slippery conditions causing poor traction = 3.

Table 3.—*Elements related to productivity*

Element	Description
Walk-to-bunch	Time to walk from bunch to bunch
Delimb-buck	Time to delimb, buck, and top all stems in a bunch
Pile	Time to stack bolts for each bunch

variable in the model was the inverse of the number of stems per bundle. The final walk-to-bunch equation was:

$$\text{WALK-TO-BUNCH} = 0.0389 + (0.1244/\text{STEMS})$$

with: $R^2 = 0.42$

Root MSE = 0.050

where:

WALK-TO-BUNCH = Productive time to walk to bunch; minutes per tree,

STEMS = Number of stems per bunch.

Delimb-Buck Element.—Average d.b.h. and bolt length proved to be the only significant variables in the final delimb-buck element prediction equation. Other variables tested in the model were trees per acre, average basal area per tree, bunch basal area, total height, crown ratio, clear-bole length, and the interactions among these variables. Average d.b.h. describes the size of the tree, while bolt length is directly related to the number of bolt cuts needed.

The data showed an almost constant delimb-buck time for bunches when average tree d.b.h. was less than 5.5 inches. A two-piece model was used to develop a regression equation. When the d.b.h. increased to greater than 5.5 inches, the delimb-buck time increased linearly.

The bolt length also had a significant effect on the time element. For an average tree d.b.h. of less than 5.5 inches, as the bolt length increased, the delimb-buck time decreased significantly. For a d.b.h. larger than 5.5 inches, the interaction of bolt length and d.b.h. significantly affected the time to delimb and buck trees in bunches. As the d.b.h. increased, longer bolt lengths required less time to accomplish the function. The final equations for the delimb-buck element were:

when d.b.h. <5.5 inches;

$$\text{DELIMB-BUCK} = 1.3018 - (0.1317 \times \text{BL})$$

and when d.b.h. ≥5.5 inches;

$$\text{DELIMB-BUCK} = -3.8710 + (0.9405 \times \text{AvDBH}) + (0.4238 \times \text{BL}) - (0.1010 \times \text{AvDBH} \times \text{BL})$$

with: $R^2 = 0.62$

Root MSE = 0.229

where:

DELIMB-BUCK = Productive time per tree in minutes,

AvDBH = Average d.b.h. in inches,

BL = Bolt length in feet.

Total Delimbing and Bucking Cycle.—By summing walk-to-bunch and delimb-buck element equations, a total time per tree equation was developed. This combined equation simplifies the use of the two equations.

The final total equations were:
when d.b.h. <5.5 inches;

$$\text{TOTAL TIME} = 1.3407 + (0.1244/\text{STEMS}) - (0.1317 \times \text{BL})$$

and when d.b.h. ≥5.5 inches;

$$\text{TOTAL TIME} = -3.8321 + (0.1244/\text{STEMS}) + (0.9405 \times \text{AvDBH}) + (0.4238 \times \text{BL}) - (0.1010 \times \text{AvDBH} \times \text{BL})$$

where:

TOTAL TIME = Productive time to walk to and delimb-buck each tree in minutes,

AvDBH = Average d.b.h. in inches,

STEMS = Number of stems per bunch,

BL = Bolt length in feet.

Piling

A summary of piling productive time per tree for the study is shown in tables 5 and 6. The piling function was distinguished between complete and partial piling. Complete piling consisted of a worker who followed the chainsaw operator and placed the bucked wood in piles. In partial piling, the chainsaw operator performed limited piling of a few upper bolts in the bunch; the wood was not piled by a separate forest worker. Average total time per tree was 0.57 minutes for complete and 0.10 minutes for partial piling.

Complete Piling.—The average delay time for the piler was 1.44 minutes per observation or 0.06 minutes per tree. The piler also carried fuel and oil for the chainsaw. There were interaction delays while waiting for the wood to be bucked, because the piler only worked with one chainsaw operator. Average delay time per tree for interaction was 0.06 minutes per tree.

The elements of the piling function were analyzed to determine which variables were significant. The walk-to-bunch was not significantly affected by the bunch characteristics, and therefore the mean time, 0.05 minutes per tree, was used in the analysis.

The actual piling time element was best predicted by the average d.b.h. and number of stems in each

Table 4.—*Elemental time per tree summary for delimbing-bucking function*

Element	South Carolina			Mississippi			Louisiana operation 1			Louisiana operation 2			Louisiana operation 3			Alabama		
	Obs.*	Mean	Std. dev.	Obs.	Mean	Std. dev.	Obs.	Mean	Std. dev.	Obs.	Mean	Std. dev.	Obs.	Mean	Std. dev.	Obs.	Mean	Std. dev.
	time per tree (min)																	
Walk-to-bunch	15	0.07	0.05	75	0.12	0.06	29	0.05	0.04	15	0.08	0.07	22	0.08	0.04	8	0.04	0.02
Delimb-buck	15	0.63	0.18	75	0.78	0.37	29	0.37	0.13	15	0.59	0.19	22	0.50	0.16	8	0.55	0.28
Total	15	0.70	0.17	75	0.90	0.40	29	0.42	0.14	15	0.67	0.20	22	0.58	0.16	8	0.59	0.29

*Obs. is equal to the number of bunches.

Table 5.—*Elemental time per tree summary for complete piling (South Carolina only)*

Element	Obs.	Mean	Std. dev.
Walk-to-bunch	13	0.05	0.04
Pile	13	0.62	0.33

Table 6.—*Elemental time per tree summary for partial piling of top bolts*

Study	Obs.	Mean	Std. dev.
Louisiana 1	27	0.06	0.03
Louisiana 2	19	0.18	0.04
Louisiana 3	10	0.05	0.02
Combined	56	0.10	0.09

bunch. Other variables were added to the model but were not significant. The final complete piling time prediction equation, including the walk-to-bunch element was:

$$\text{COMPLETE PILING} = 0.3962 + (0.1565 \times (\text{AvDBH/STEMS}))$$

with: $R^2 = 0.79$

Root MSE = 0.158

where:

COMPLETE PILING = Productive time per tree in minutes,

AvDBH = Average d.b.h. in inches,

STEMS = Number of stems per bunch.

Partial Piling.—For the partial piling function, the chainsaw operator put his saw down and piled the top bolts. The number of stems per bunch was the only significant variable in the model. The final prediction equation for partial piling was:

$$\text{PARTIAL PILING} = 0.6472/\text{STEMS}$$

with: $R^2 = 0.68$

Root MSE = 0.076

where:

PARTIAL PILING = Productive time per tree in minutes,

STEMS = Number of stems per bunch.

Partial piling was only completed in the Louisiana operations. All studies with partial piling averaged 6.7 trees per bunch, and the designated bolt length was 7.5 ft. The number of bolts to be piled was determined by the operator and apparently was a function of the merchantable limit of the diameter of the top bolts bucked from the stems.

APPLICATION

Productivity

Analysis of the data resulted in prediction equations or averages that can be used to establish production rates for the range of conditions of the study. For delimbing and bucking, the production rate in trees per productive hour was determined for a range of bolt lengths and bunch sizes as shown in table 7. The bunch sizes were generated by using number of stems and average d.b.h. combinations. Table 7 can be used to estimate productivity for a range of tree diameters and stems per bundle. For more detailed analysis, the elemental time equations could be used for estimations. It is very important to stay within the limits of the conditions from which the equations were developed. The average productivity for the delimbing and bucking function was 91 trees per hour.

Using the piling equation with the average walk-to-bunch time, a production table was developed for the manual piling function. The productivity in trees per hour is shown in table 8. Again, the estimated rates are shown for a range of tree and bundle sizes. The average productivity for the piler in the study was estimated from the table to be 103 trees per productive hour.

By combining the total time equation for delimbing and bucking with the partial piling equation, the production rates (trees per productive hour) for a chainsaw operator who is also partially piling can be determined. These rates are shown in table 9 for a 7.5 ft bolt length.

Costs.—Machine-rate costs have been determined for chainsaw operations, with separate cost estimates made for piling (Miyata 1980). Costs were calculated as dollars per productive hour.

Operating costs:	Cost of one chainsaw divided by 1,000 productive hours/year ($480/1,000)	$ 0.48

	Gas, oil, repair and maintenance (from Cubbage 1981)	3.00
Labor costs:	$5.00 per scheduled hour plus 30% fringe benefits ($6.50/ 50% utilization)	13.00
Total cost per productive hour for chainsaw operation:		$16.48
Piling costs:	$4.50 per scheduled hour plus 30% fringe benefits ($5.85/ 50% utilization)	$11.70

The only cost for piling would be labor costs. The operating costs would rise if the cost of a spare chainsaw were included. The 50-percent utilization rates for labor are estimates for year-round operations. Utilization would probably be less during summer months.

By combining the production tables and volumes, estimates of cunits (100 ft^3 of solid wood) per productive hour were developed. Using the estimated cost per productive hour for chainsaw operator and piler, cost per cunit of wood was determined. The delimbing and bucking function rates and costs are shown in table 10. Piling productivity rates and costs are shown in table 11. Delimbing and bucking with partial piling productivity and cost rates are shown in table 12. Comparison of Tables 10 and 11 give the incremental costs of partial piling. These tables can be used to estimate costs at various bunch sizes for a range of tree sizes and bolt lengths.

SUMMARY AND CONCLUSIONS

Several thinning operations were evaluated to determine productivity and cost for perparing wood to be moved by a forwarder. The trees were felled and bunched with a feller-buncher. Prediction equations were developed where possible; means were used when statistically significant relationships were not found.

For this study, the evaluation showed an average production of 3.2 cunits per productive hour for the delimbing and bucking function at a cost of $5.14 per cunit. Production for the piling function was 3.3 cunits per productive hour for 6.5-ft bolts and cost $3.55 per cunit for the average conditions of the study. Delimbing and bucking with partial piling (7.5-ft bolts only) was 3.9 cunits per hour at a cost of $4.24 per cunit.

Table 7.—*Chainsaw delimbing and bucking function of bunched trees*

		Trees per bunch			
Bolt length	D.b.h.	2	4	8	16
feet	*inches*	*trees per productive hour*			
5.25	5	84	88	* 90	91
	6	65	68	69	70
	7	45	46	47	47
	8	34	35	35	36
6.5	5	110	116	120	122
	6	87	91	93	95
	7	62	64	65	65
	8	48	49	50	50
7.5	5	145	156	163	166
	6	118	126	130	133
	7	87	91	93	94
	8	69	71	73	73

*Boxed-in areas indicate range of data.

Table 8.—*Manual piling of bunched trees*

Bolt length	D.b.h.	Trees per bunch			
		2	4	6	8
feet	*inches*	*--- trees per productive hour ---*			
6.5	5	76	101	114	122
	6	69	95	109	117
	7	64	90	104	113
	8	59	85	99	109

Table 9.—*Chainsaw delimbing and bucking combined with piling top bolts*

Bolt length	D.b.h.	Trees per bunch		
		4	8	16
feet	*inches*	*--trees per productive hour -*		
7.5	5	110	134	149
	6	94	111	122
	7	73	83	88
	8	60	66	70

Table 10.—*Production and costs for delimbing and bucking function*

Bolt length	D.b.h.	Total height	Trees per bunch*			
			2	4	8	16
feet	*inches*	*feet*	*----------cunits per productive hour ----------*			
5.25	5	40	1.8 †† (9.14)	1.99 (8.74)	1.9 (8.54)	2.0 (8.44)
	6	43	2.3 (7.16)	2.4 (6.92)	2.4 (6.79)	2.4 (6.73)
	7	47	2.4 (6.87)	2.5 (6.71)	2.5 (6.63)	2.5 (6.59)
	8	49	2.5 (6.52)	2.6 (6.41)	2.6 (6.35)	2.6 (6.32)
6.5	5	40	2.4 (7.03)	2.5 (6.63)	2.6 (6.43)	2.6 (6.33)
	6	43	3.1 (5.38)	3.2 (5.14)	3.3 (5.02)	3.3 (4.96)
	7	47	3.3 (5.04)	3.4 (4.87)	3.4 (4.79)	3.5 (4.75)
	8	49	3.5 (4.72)	3.6 (4.60)	3.6 (4.54)	3.6 (4.51)
7.5	5	40	3.1 (5.33)	3.3 (4.93)	3.5 (4.73)	3.6 (4.63)
	6	43	4.2 (3.96)	4.4 (3.71)	4.6 (3.59)	4.7 (3.53)
	7	47	4.6 (3.57)	4.8 (3.41)	5.0 (3.33)	5.0 (3.29)
	8	49	5.0 (3.28)	5.2 (3.16)	5.3 (3.10)	5.4 (3.07)

*Top merchantable limit of 3 in (o.b).

†Boxed-in areas indicate range of data.

††Numbers in parentheses equal dollar cost per cunit for respective bolt length, d.b.h., height, and trees per bunch.

Table 11.—*Production and cost for manual piling*

Bolt length	D.b.h.	Total height	Trees per bunch			
			2	4	6	8
feet	*inches*	*feet*	*cunits per productive hour*			
6.5	5	40	1.6 (7.31)*	2.1 (5.57)	2.4 (4.88)	2.5 (4.68)
	6	43	2.4 (4.88)	3.3 (3.55)	3.8 (3.08)	4.0 (2.93)
	7	47	3.3 (3.55)	4.6 (2.54)	5.3 (2.21)	5.8 (2.02)
	8	49	4.1 (2.85)	5.9 (1.98)	6.9 (1.70)	7.6 (1.54)

*Numbers in parentheses equal dollar cost per cunit for the respective bolt length, d.b.h., height, and trees per bunch.

Table 12.—*Production and cost for delimbing and bucking combined with partial piling top bolts*

Bolt length	D.b.h.	Total height	Trees per bunch		
			4	8	16
feet	*inches*	*feet*	*cunits per productive hour*		
7.5	5	40	2.3 (7.13)*	2.8 (5.86)	3.1 (5.27)
	6	43	3.3 (5.01)	3.9 (4.24)	4.3 (3.86)
	7	47	3.9 (4.26)	4.4 (3.75)	4.7 (3.53)
	8	49	4.3 (3.81)	4.8 (3.47)	5.0 (3.27)

*Numbers in parentheses equal dollar cost per cunit for the respective bolt length, d.b.h., height, and trees per bunch.

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Studies were made of subsequent functions of bunched trees in southern pine plantation thinnings. Prediction equations, production rates, and cost estimates were developed.

Keywords: Chainsaw, feller-buncher, productivity rates.

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Regeneration After Shear Felling and Chipping of Upland Hardwoods

Charles E. McGee

SUMMARY

Low-quality hardwood stands on the Cumberland Plateau and the Western Highland Rim were harvested by shear felling and on-site chipping. Methods for introducing loblolly pine (*Pinus taeda* L.), white pine (*P. strobus* L.), shortleaf pine (*P. echinata* Mill.), and yellow-poplar (*Liriodendron tulipifera* L.) seedlings into these stands with minimum or no site preparation were explored. The effect of limited site preparation on natural regeneration was also evaluated. The desirability of intentional development of planted pine-natural hardwood mixtures was studied. Intensive harvest was found to be a key to reduced site preparation needs.

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Regeneration After Shear Felling and Chipping of Upland Hardwoods

Charles E. McGee

INTRODUCTION

A great acreage of low-quality forest has developed in the Cumberland Plateau region because of fire, poor cutting practices, insects, disease, and poor site quality (McGee 1982). A key to improved management of these low-quality stands, many of which need to be regenerated, is intensive utilization of the low-quality products generally found on the area.

Intensive utilization, in concept, accomplishes several goals. First, it implies that most of the timber on an area will be used by the purchaser and therefore stumpage returns will be greater than would be the case with less intensive utilization. Second, intensive utilization removes most of the low-quality trees and reduces the effort needed to prepare the area for the next crop of trees. Intensive utilization can range from traditional pulpwood and sawlog removal with firewood cutting to shear felling and on-site chipping as discussed in this paper.

The process of shear felling and whole-tree chipping has many silvicultural advantages in the Cumberland Plateau region, but there can also be problems. The practicality of felling trees by shearing and then chipping whole trees on the site depends to a great extent on the lay of the land and access. The rolling slopes of the plateau tops and much of the Eastern and Western Highland Rim are conducive to shearing. However, the steepness of some of the slopes on the Western Rim, the Ridge and Valley, and the Plateau Escarpment precludes the use of mechanized shearing. Efficiency of operation also requires sizable acreages in order for a harvesting operation to be worthwhile to a logging contractor. If the chipping is to be done on site, as reported here, the chip vans require good roads.

Problems can be caused by very large trees and/or many very small trees. The intensity of the problems caused by large and small trees depends to a great extent on the kind of equipment used. Some workers have observed that sheared hardwoods tend to sprout less than those cut with chain saws (Miller and Phillips 1984). A problem to guard against is a tendency to shear and chip trees that could be used for higher value products. This wasteful practice can be avoided by logging high-quality trees in advance of the shearing or by collecting the high-quality logs separately as part of the skidding and shearing process.

This paper documents regeneration response 5 years after shear felling on the Cumberland Plateau and 3 years after shear felling on the Western Highland Rim. Both natural and artificial regeneration are evaluated on these areas. Since the harvesting and regeneration procedures reported here involve minimal or no site preparation, attention has been given to the development of natural hardwoods in planted stands. The pros and cons of the resulting mixed stands are discussed, with particular emphasis on the loblolly pine-hardwood mixture. Earlier results have been reported in previous papers (McGee 1980, Sims and others 1981).

THE CUMBERLAND PLATEAU

Objectives

This study compared the growth and development of planted loblolly pine, white pine, and yellow-poplar (see Appendix for scientific names) to natural regeneration on sites where all standing vegetation >4 inches d.b.h. has been sheared and chipped. Evaluations were made of what effects herbicide injection of residual trees had on stand development.

Study Area

The study area, on land belonging to the University of the South near Sewanee, TN, was typical of Cumberland Plateau land that has been logged and burned at irregular intervals. The 37-acre area, classified as landtype 1 (Smalley 1982), has broad undulating ridges with occasional outcroppings of rock. The soil is mostly Hartsells sandy loam. Site indexes ranged from 55 to 75 feet for oak at 50 years. Accurate site-quality appraisals were impossible to obtain because suitable overstory index trees were lacking, but the site is capable of producing better timber than was harvested at the time the study began.

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Before harvest, the study area supported a sparse overstory, many intermediate trees, and a variety of plants in the understory (table 1). The overstory contained about 135 trees per acre, mostly scarlet oak and white oak. Almost all of the overstory trees over 12 inches d.b.h. were culls from previous harvests. Only about 30 trees on the area were of sawtimber size and quality. Some intermediate trees, over 4.5 feet tall but less than 5 inches d.b.h., had invaded the area following irregular cutting, but many intermediate trees, particularly white oak, were 60 to 80 years old.

There were 7,050 stems per acre less than 4.5 feet tall. Most were very small, and distribution was variable. Because of large relicts and many small stems, this tract was less than optimal for shearing and chipping, but it was typical for the Cumberland Plateau.

Harvest

The harvest began in September 1976 and was completed by November. Trees sheared by a tracked feller-buncher were skidded to a central site and fed into the chipper. Chips were stored on the ground and hauled to the pulpmill. The 30 sawtimber trees scattered throughout the stand were cut with chain saws.

The 37 acres yielded about 1,200 green tons of chips (32.4 tons/acre). In the shearing operation, almost all stems ≥4 inches d.b.h. were felled. However, from 50 to 500 stems per acre (mostly 2 to 3 inches d.b.h.) remained on the site (figs. 1 & 2).

The major impact of logging on soil occurred at the central chipping location. The skidding, piling of chips, and hauling shown in figures 3 and 4 affected 1.5 acres, of which 0.75 acre was seriously compacted. Little soil movement resulted from logging disturbance, and no soil deposition was observed in Jackson Lake a few hundred feet away.

Design

Twenty-four 1-acre plots were established away from the central area of compaction, and within each 1-acre plot a central area slightly larger than 0.25 acre was delineated for measurements. Six plots each were randomly designated for: (1) planting 1.0 loblolly pine, (2) planting 2.0 white pine, (3) planting 1.0 yellow-poplar, and (4) natural regeneration. All residual trees >4.5 feet tall on three randomly selected plots in each of the four categories were injected with herbicide (picloram plus 2,4-D) during the winter following harvest. Plots receiving this treatment are referred to as "injected plots." Plots not receiving the herbicide treatment are referred to as "uninjected."

Seedlings were planted in March 1977 at 8- by 10-foot spacings. Survival, height, and relationship to competition were determined on the central measurement areas; these measurement areas contained 143 seedlings, with each planting space representing an 8- by 10-foot subplot. So that comparisons could be made between natural regeneration and planted trees, 143 8- by 10-foot subplots were established in each of the 6 plots assigned to natural regeneration. Heights of planted seedlings were compared to the heights of the tallest desirable tree on each natural regeneration subplot.

Results

Survival.—After five growing seasons, survival of planted loblolly pine, white pine, and yellow-poplar was ≥90 percent (table 2). The small amount of mortality between the second and fifth year was quite surprising because growing conditions were less than ideal due to several droughts and a severe ice storm. In natural regeneration areas after five growing sea-

Table 1.—*Preshearing inventory of a Cumberland Plateau forest*

Species	Stem Size			
	Height <4.5 feet	Height >4.5 feet; d.b.h. <5 inches	d.b.h. ≥5 inches	Stems per acre (average)
	..... *Number Per Acre*			
Blackgum	1050	350	1	1401
Red maple	575	140	2	717
Dogwood	2400	220	5	2625
Sassafras	1450	170	...	1620
Hickory	275	278	16	569
White oak	600	462	45	1107
Post oak	....	10	12	22
Black oak	250	155	12	417
Scarlet oak	150	58	41	249
Sourwood	175	355	1	531
Yellow-poplar	25	....	...	25
Other species	100	38	...	138
Total	7050	2236	135	9421

Figure 1.—*A low-quality hardwood stand on the Cumberland Plateau following harvest by shearing with a tracked feller-buncher to a 4-inch diameter limit.*

Figure 2.—*Trees harvested by shear-felling waiting to be chipped.*

Figure 3.—*Tree being fed into chipper; chips are being piled before loading.*

Figure 4.—*Chips being loaded into a van; vans require roads that are in relatively good condition.*

Table 2.—*Survival of planted seedlings and natural regeneration on the Cumberland Plateau*

Species	Survival at 2 years		Survival at 5 years	
	Injected[1]	Not injected	Injected	Not injected
	Percent			
Loblolly pine	94	96	91	92
Yellow-poplar	98	99	96	97
White pine	95	96	90	93
Natural regeneration[2]	92	83	87	73

[1]Injected = plots where hardwoods >4.5 inches d.b.h. were injected with picloram 2,4-D; not injected = plots where hardwoods were not injected.

[2]Numbers in this row indicate percentage of subplots that contain at least one white oak, scarlet oak, black oak, yellow-poplar, black cherry, hickory spp., or other desirable species.

sons, 80 percent of the 8- by 10-foot subplots contained one or more white oak, scarlet oak, black oak, yellow-poplar, hickory spp., black cherry, or other desirable species. The number of subplots containing desirable trees dropped by about 7 percent between the second and fifth year (table 2).

Height Growth.—Two years after study initiation there was little difference among average heights or heights of the tallest trees among planted loblolly pine, planted yellow-poplar, and desirable natural regeneration, but all were taller than planted white pine (table 3).

After 5 years, loblolly pines were substantially taller than yellow-poplar, white pine, or desirable natural regeneration. However, due to a great deal of within-plot variation, analyses of variance were not significant. Desirable natural trees growing on plots that had not received the injection treatment were taller than those growing on injected plots. Height ranges for the 200 tallest planted trees per acre/over the 6 plots after 5 years were: loblolly pine, 12.7 to 14.6 feet; white pine, 6.5 to 7.0 feet; yellow-poplar, 8.2 to 10.7 feet; and desirable natural saplings, from 7.8 to 11.7 feet.

Within-plot variation for average heights after 5 years was substantial for all species except white pine. However, calculated variances are greatly reduced when only the 400 and 200 tallest trees per acre are included. Loblolly pines planted in injected plots (fig. 5) are much more uniform in height than those planted in plots where residuals had not been injected (fig. 6). Variances in height for the average, 400 tallest, and 200 tallest loblolly stems per acre were (respectively) 4.54, 1.70, and 0.76 for injected plots compared to 7.69, 3.14, and 1.26 on plots not receiving the injection treatment. Variances in height for the desirable natural stems in injected plots were 7.66, 4.92, and 2.41 for average, 400 tallest, and 200 tallest stems per acre, respectively, compared to 13.18, 11.81, and 3.80 for plots not receiving the injection treatment.

Competition.—Shearing to a 4-inch d.b.h. limit had left occasional dense clumps of red maple, sourwood,

Figure 5.—*Three-year-old loblolly pines planted on sheared area where residual hardwoods had been injected with herbicide.*

Figure 6.—*Three-year-old loblolly pines planted on sheared area with no additional site preparation. Many of the residual hardwoods have increased substantially in size and provide serious competition to individual planted loblolly.*

Table 3.—*Average heights of planted seedlings and natural regeneration two and five growing seasons after shear felling on the Cumberland Plateau*

Species	Treatment of residuals	After 2 years			After 5 years		
		Stand average	Tallest 400 per acre	Tallest 200 per acre	Stand average	Tallest 400 per acre	Tallest 200 per acre
		Feet					
Loblolly pine	Injected	3.7	4.1	4.6	11.7	12.5	13.6
	Not injected	3.7	4.0	4.5	10.5	11.8	13.2
Yellow-poplar	Injected	3.0	3.4	4.0	6.3	7.2	8.7
	Not injected	3.2	3.6	4.2	7.2	8.2	9.5
White pine	Injected	1.5	1.7	2.0	5.1	5.8	6.7
	Not injected	1.6	1.8	2.0	5.0	5.7	6.7
Natural regeneration[1]	Injected	2.7	3.3	4.3	6.3	7.2	9.0
	Not injected	3.6	4.2	5.7	7.9	8.3	11.0

[1]Natural regeneration includes white oak, scarlet oak, yellow-poplar, black oak, hickory spp., black cherry, and others.

Table 4.—*Competitive position of planted trees in relation to hardwood residuals 5 years after shear felling on the Cumberland Plateau*

Species	Residuals injected[1]			Residuals not injected		
	Free to grow	Not free to grow	Dead	Free to grow	Not free to grow	Dead
	Percent					
Loblolly pine	62	28	9	32	61	7
Yellow-poplar	5	91	3	6	92	2
White pine	31	88	10	20	72	8

[1]Residual hardwoods >4.5 inches d.b.h. were injected with picloram 2,4-D prior to planting of seedlings.

dogwood, sassafras, blackgum, oaks, and other species, while sizable patches had little or no vegetation. Herbicide injection had reduced the number of live residuals over 4.5 feet tall from about 400 to 32 per acre on the 12 plots receiving this treatment.

Height growth of planted trees did not show much variation between injected and uninjected plots after either 2 or 5 years. However, seedlings planted on injected plots had a stronger crown position; loblolly seedlings in particular had a very high percentage of free-to-grow seedlings on the injected plots (table 4). Only 8 percent of the loblolly planted on injected plots were judged to be seriously affected by competition while 36 percent were seriously affected in uninjected plots. About one-half of the yellow-poplar and one-third of the white pine were seriously affected by the hardwood competition on injected plots (fig. 7).

Distribution of Natural Regeneration.—The distribution of desirable natural regeneration had not changed much between the second and fifth growing seasons. White oak, scarlet oak, black oak, and hickory continued to be the tallest and best distributed of the desirable species (table 5) (fig. 8). The subplots lacking desirable stems increased from 12 to 15 percent. About 35 to 40 percent of the desirable stems described in table 5 were free to grow. Some of the desirable stems received competition from residual trees in the uninjected plots, and some of the competition was from stems of other desirable species. How-

Figure 7.—*Five-year-old planted white pine on sheared area where residuals were injected with herbicide.*

Table 5.—*Distribution of desirable natural regeneration in unplanted plots on the Cumberland Plateau by number of subplots occupied by a particular species*

Tallest desirable species	After 2 years	After 5 years
	Subplots Per Acre[1]	
White oak	216	192
Scarlet oak	132	124
Black oak	72	64
Yellow-poplar	24	20
Hickory spp.	28	64
Black cherry	16	12
Other species	12	12
No desirable species present	72	84

[1]Numbers are based upon the tallest desirable stem in each of the 8- by 10-foot subplots. For example, white oak was the tallest desirable tree on 216 subplots per acre after 2 years.

ever, most of the competition to desirable natural regeneration was from the several hundred sourwood, dogwood, blackgum, and other stems per acre that had resprouted.

Loblolly Pine-Hardwood Mixture.—It now appears that even on the injected plots, where 62 percent of the planted loblolly were free-to-grow, the subsequent stand will be a pine-hardwood mixture. On the uninjected plots, where 32 percent of the loblolly were free-to-grow and 36 percent were judged to be seriously affected by the competition, hardwoods will be a more important factor. While freedom to grow is an important consideration in evaluating a tree's future prospects, the actual height of the tree in relation to competition is also of interest. All of the free-to-grow trees were taller than the competition, but not all of the loblolly taller than the competition, were judged completely free-to-grow. When the heights of the loblolly pine on each subplot are compared to the heights of competing hardwoods (fig. 9), the considerable influence of the injection treatment is apparent.

After 2 years, only 26 percent of the loblolly on injected plots was as tall or taller than all other vegetation on each subplot. This percentage increased markedly each year so that after 5 years, 84 percent of the loblolly pines matched or exceeded the height of the hardwoods. If desirable hardwoods are included where either a pine is dead or where a taller competing hardwood is a desirable species, the percentage of planted pine plus desirable hardwoods that are taller than the competition increases to 37 and 90 percent after 2 and 5 years.

On the uninjected plots only 11 percent of the planted loblolly were as tall or taller than the competition after 2 years, and after 5 years the percentage increased to 52 percent. Including desirable hardwoods where pines have died or where a desirable hardwood is tallest on the subplot increases the percentage to 26 percent and 58 percent after 2 and 5 years.

While it is risky to forecast what will be the ultimate outcome in the struggle between the pines and the desirable and undesirable hardwoods, some short-term predictions can be made. The steady increase in dominance of pine and pine plus desirable hardwoods on the injected plots from 2 through 4 years and a slight decrease in the rate of increase between years 4 and 5 suggest that by age 10, at least 80 percent of the subplots will be occupied by a dominant pine or desirable hardwood (fig. 9). However, it is sheer speculation as to how long the increase in pine dominance

Figure 8.—*Five-year-old natural oak regeneration following shearing and injection of residuals.*

will continue on the untreated plots. A guess is that the percentage of the pines that are as tall or taller than the competition will not increase much more. Thus, at age 10, a 60 percent stocking of subplots with a dominant pine or desirable hardwood on the untreated areas may be a good estimate.

THE WESTERN HIGHLAND RIM

Objectives

Study objectives were to compare the growth and development of planted loblolly pine, shortleaf pine, and yellow-poplar to natural regeneration in stands where all stems >1 inch d.b.h. had been sheared and chipped and to evaluate the effect of no additional site preparation on stand development.

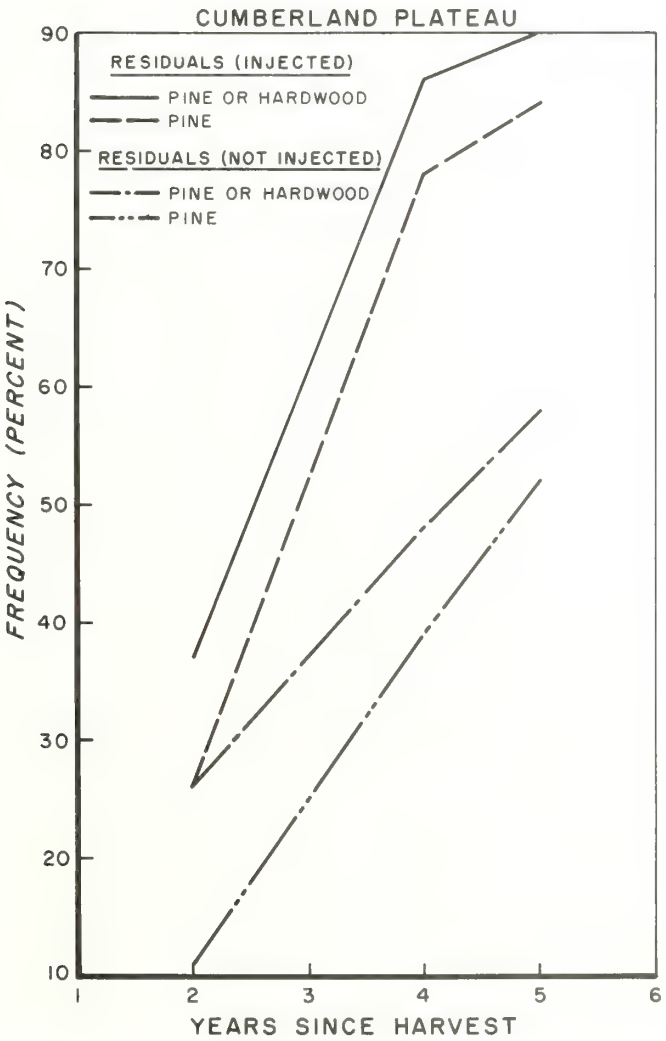

Figure 9.—*Frequency of pine or desirable hardwood being the tallest tree on an 8- by 10-foot subplot.*

Study Area

The 40-acre study area is typical of much of the hardwood forest of the Western Highland Rim. It is located in Humphreys County on the Duck River tract of land owned by Koppers Co. near Buffalo, TN. The area is characterized by narrow ridges containing Dickson silt loam shallow phase soil along the ridgetops. Soils along the slopes are mainly cherty Bodine. The hollows contain Humphreys silt loam soils. Site index, as roughly determined by on-site measurements, ranged from 57 to 74 feet for oak at 50 years.

Vegetation on the area was characterized by a moderate overstory, many intermediate stems, and an understory containing a wide variety of plants. The overstory contained about 190 stems per acre. Basal area averaged approximately 75 square feet per acre and included numerous culls and residuals left from logging 20 years earlier. White oak, hickory spp., post oak, and scarlet oak were the major overstory species. Black oak and sourwood were also present in the overstory. Blackgum, white oak, dogwood, the hickories, post oak, and sourwood were the chief components of the midstory. Scarlet oak, white ash, and sassafras were also part of the midstory, along with a few yellow-poplar. The understory contained 3,431 trees and 2,243 shrubs per acre.

The Harvest

Harvesting began in September 1980 and was completed in October. Trees were sheared by a rubber-tired feller-buncher (fig. 10) to a 1-inch d.b.h. limit. Most of the remaining stems were pushed over or broken during skidding. The trees were skidded to one of several chipping areas and decked until they could be fed into the chipper. The chips were fed directly into waiting vans.

After the skidding, the ridges and gentle slopes had a clean-swept look (fig. 11). In the narrow, steep hollows a few trees could not be reached by the feller-buncher, and about 20 trees were too large for the shear. These trees were felled by chain saw.

Study Design

The study contains thirty two 1-acre plots in 4 blocks in a completely randomized block design. Each block contains two plots each of planted loblolly pine, planted yellow-poplar, and planted shortleaf pine, and two plots designated for natural regeneration. One plot of each planted species and one plot of natural regeneration in each block was designated to receive competition control. At the time of this report no competition control beyond the initial harvest had been imposed on any of the plots. Each of the 32 plots contains a central measurement area slightly larger than 0.25 acre.

Figure 10.—*Hydro-Ax shearing low-quality white oak on Western Highland Rim.*

The loblolly, shortleaf, and yellow-poplar were planted in March 1981 at a 10- by 10-foot spacing. Comparisons between the planted seedlings and natural regeneration were made possible by identifying 121 10- by 10-foot subplots in each of the measurement plots selected for natural regeneration.

Survival and height measurements for loblolly, yellow-poplar, and natural regeneration were made 2 and 3 years after the study began. Unfortunately, almost all the planted shortleaf died shortly after the initial planting and were replanted a year later. Therefore, shortleaf pines are 1 year younger than other species.

Results

Survival.—After 2 growing seasons, survival ranged from acceptable to excellent (table 6). Only 3 of 968 planted yellow-poplars had died on the 8 measurement plots. Loblolly survival also was very good. In the unplanted natural stands, 80 percent of the subplots contained a desirable tree. The replanted shortleaf had a relatively low but acceptable 78 percent survival.

Following a drought during the third growing season and intensified attacks on loblolly pine by tip moths and sawflies, overall mortality increased along with the likelihood of future seedling loss (table 7). After 3 years, the survival of yellow-poplar was holding at 99 percent. However, 273 of the yellow-poplar suffered severe top dieback toward the end of the third growing season, and it is likely that many of these will not survive (table 8). Loblolly survival dropped to 89 percent. Survival on one plot of loblolly that had intensive sawfly infestation dropped from 93 to 80 percent. Survival of shortleaf decreased to 68 percent. Natural regeneration stocking after 3 years was holding at 80 percent.

Table 6.—*Survival of planted and natural regeneration after 2 and 3 growing seasons on the Western Highland Rim*

Species	Survival at 2 years	Survival at 3 years
	Percent	
Loblolly pine	94	89
Yellow-poplar	100	99
Shortleaf pine[1]	78	68
Natural mixture[2]	88	80

[1]Shortleaf were replanted; measurements are for survival at 1 and 2 years.

[2]Numbers indicate percentage of subplots that contain a white oak, scarlet oak, black oak, yellow-poplar, black cherry, hickory spp. or other desirable species.

Because planting of loblolly pine is widespread throughout the Western Highland Rim, mortality and damage to loblolly is worthy of careful study. After 2 years, 159 of the 913 loblolly pines had been damaged by sawflies (table 7). In addition, 91 seedlings had been damaged by tip moth and 38 had been browsed by deer. One year later, 641 loblolly pines (74 percent) had heavy tip moth damage, but only 6 showed any evidence of sawfly damage. Of the 50 loblolly pines that had died between the second and third growing seasons, most had been completely stripped by sawflies during the second (1982) growing season.

Height Growth.—Height growth for natural regeneration, planted loblolly (fig. 12), and yellow-poplar after the second growing season was generally acceptable, but height growth was disappointing following an exceedingly hot and dry 1983 growing season (table 9). Between years 2 and 3 the average height growth of yellow-poplar was only 1.2 feet and that of the tallest 200 trees averaged 1.7 feet. Consequently, only 121 (12 percent) of the yellow-poplar were as tall, or taller than their hardwood competitors.

The average loblolly grew from 3.8 feet to 5.3 feet between years 2 and 3; the tallest 200 per acre grew from 4.6 feet to 6.4 feet. About one-third of the loblolly were as tall or taller than adjacent hardwood competitors.

Desirable natural hardwood regeneration also showed the effects of the drought. Between years 2 and 3, average height increased only 1.7 feet for all

Figure 11.—*Two sites on the Western Highland Rim where low-quality hardwood stands had been sheared to a 1-inch d.b.h.*

Table 7.—*Insect damage to planted loblolly pines on the Western Highland Rim*

Year	No damage	Sawfly damage		Tip moth damage		Total number of trees
		Moderate	Heavy[1]	Moderate	Heavy	
			Number of Trees[2]			
1982 (2nd)	663	109	50[3]	91	....	913
1983 (3rd)	4	6	0	212	641	863

[1]Heavy = needles completely stripped from tree.
[2]Number includes loblolly planted on the eight 1/4-acre measurement plots.
[3]The 50 trees stripped by sawfly larvae made up the total loblolly pine mortality between 1982 and 1983.

Table 8.—*Dieback of planted yellow-poplar on the Western Highland Rim following the 1983 (third) growing season*

Living trees[1]	Amount of dieback		
	None	Partial	Complete
		Number	
962	574	115	273

[1]Trees living at end of 1983 growing season on the eight 1/4-acre measurement plots.

trees and 1.8 feet for the 200 tallest trees per acre.

The replanted shortleaf, 1 year behind the other planted species and the natural competition, did not grow much during the first growing season, and height growth between the first and second growing seasons was almost nil. The 1-year loss in growth, the drought, and deer browsing made it unlikely that the shortleaf could compete with the natural hardwood competition unless released.

Competition.—Residual standing vegetation following the shearing to a 1-inch d.b.h. limit was almost nonexistent. Only a few trees taller than 4.5 feet were left standing, and these were usually on the lower slopes where shearing and skidding were restricted. Thus all planted trees, desirable natural regeneration, and undesirable hardwoods began growth with complete freedom from overhead shade. The exception was the replanted shortleaf, which was shaded by competitors at the time of planting.

Distribution of Natural Regeneration.—White oak, hickory, yellow-poplar, and white ash made up over half the component of tallest desirable stems on the eight natural regeneration plots after 2 years (table 10). Due to the extremely hot and dry growing season the following year (1983), yellow-poplar and white oak dropped in frequency of occurrence. Yellow-poplar, in particular, declined, dropping from being the tallest desirable stem on 45 subplots per acre to being the tallest desirable on only 28 subplots per acre. Oaks will likely dominate the new stand, since they are the tallest desirable tree on about 200 of the 435 subplots per acre. After 3 years, about 62 percent of the tallest desirable trees on each plot were taller than the other competing hardwoods.

The Loblolly Pine-Hardwood Mixture.—Two years after planting, 21 percent of the loblolly was at least as tall as the competing hardwoods (fig. 13). However, if subplots are included where a desirable hardwood was the tallest hardwood, the stocking of dominant

pine plus dominant desirable hardwoods becomes 50 percent. One year later, the percentage of subplots with a dominant pine had increased to 36 percent, and the percentage of subplots with a dominant pine or a dominant desirable hardwood had increased to 65 percent.

As part of the original study design, release was planned for four of the eight loblolly plots. At this time it appears that selective release could substantially improve the competitive position of about 60 percent of the loblolly. However, between years 2 and 3, about 16 percent of the loblolly improved their competitive position, and the trend appears to be for more pine to express dominance in the future. It appears that 50 to 60 percent of the loblolly will be dominant by age 5. Therefore, no release will be performed until the rate of recruitment into the dominant category drops significantly.

Figure 12.—*Two-year-old loblolly planted on area that had been sheared to a 1-inch d.b.h. on the Western Highland Rim.*

DISCUSSION

Low-quality hardwood stands often constitute major problems for forest managers who wish to increase the productivity of their forests. Intensive harvesting of low-quality stands as described in the above two studies provides numerous regeneration options. It is clear that intensive harvest can lead to relatively inexpensive natural or artificial regeneration. It is also clear that while certain levels of artificial regeneration successes can be achieved at very low cost, the level of success will increase with increased effort in site preparation. Another important point is that the sites described on the Cumberland Plateau and on the Western Highland Rim are at best only moderate sites for hardwood growth. Thus, the favorable results obtained from limited site preparation described here will not be reproduced on better sites where the competition from hardwoods would be more intense.

The results reported suggest three pathways for regeneration. These pathways are natural regeneration, artificial regeneration, and the deliberate development of planted pine-natural hardwood mixtures. Each method has advantages and disadvantages, the importance of which depends largely on the owner's or manager's objectives.

The natural hardwood regeneration that has developed following shearing to either a 4-inch or 1-inch d.b.h. limit has been very encouraging. The overall distribution of desirable trees has been good, and the relative dominance of desirable hardwoods over undesirable hardwoods is generally acceptable for all natural regeneration plots in both study locations. Thus it appears that if a low-quality stand is sheared, particularly to the 1-inch d.b.h. limit, no additional treatment is needed to insure the development of an acceptable stand of desirable hardwoods. One must recognize, however, that on these mediocre to moderate sites the volume of high-quality hardwood material produced will be limited. Nevertheless, these new

Table 9.—*Average height and competitive position of planted trees and natural regeneration on the Western Highland Rim following shear-felling*

Species	After 2 years			After 3 years		
	Average height	Height of tallest 200 trees per acre	Tree tallest[3] planted or desirable	Average height	Height of tallest 200 trees per acre	Tree tallest planted or desirable
	Feet		*Percent*	*Feet*		*Percent*
Loblolly pine	3.8	4.6	21.00	5.3	6.4	36
Yellow-poplar	2.8	3.6	7.00	4.0	5.3	12
Shortleaf pine[1]	0.9	1.1	0.24	. . .	. . .	. .
Natural regeneration[2]	3.9	5.6	50.00	5.6	7.4	62

[1]Shortleaf heights are for seedlings outplanted 1 year; there was very little growth the second year, so no data is listed for second-year growth.
[2]Heights of natural regeneration are based upon the tallest desirable tree in each of the 10- by 10-foot subplots.
[3]Percent of plots where the tallest tree was either a planted tree or a desirable hardwood.

stands will be far better than the low-quality stands that were harvested. The new stands will also be of considerable value for wildlife, as dominant oaks are plentiful in both areas. If natural regeneration is the goal, and only trees over 4 inches d.b.h are sheared, leaving large groups of residuals, chain saw felling of these residuals will provide release and a source of vigorous sprouts. A herbicide should *not* be used on oaks and other desirable species as was done in this study.

The effectiveness and advantages of artificial regeneration following shearing depend on the species planted and the needs of management. White pine offers tremendous opportunities for some landowners on the Cumberland Plateau. Large volumes of white pine can be grown on relatively poor sites in 40 to 60 years. Planting white pine following shearing is a good procedure. However, the slow early growth of white pine may make release in 4 to 6 years necessary in order to maintain a substantial number of dominant white pines in the stand. Actually, the herbicide injection applied at the time of shearing has not greatly favored the growth of white pine. A less expensive, more reasonable approach would be to plant white pine with no herbicide treatment following shearing, and then use release as needed at a later date.

Yellow-poplar survival was very high on both the Cumberland Plateau and the Western Highland Rim. However, height growth was less than spectacular at both locations. Because of poor height growth, only a small percentage of the yellow-poplar was free to grow, even on herbicide-injected plots on the Plateau. Thus the component of yellow-poplar that will ultimately prevail in these stands is highly speculative. Release would improve the chances of yellow-poplar becoming dominant, but site quality at both locations would preclude the production of large volumes of high-quality material.

Table 10.—*Distribution of desirable natural regeneration on unplanted plots on the Western Highland Rim by number of subplots occupied by a particular species*[1]

Tallest desirable species	After 2 years	After 3 years
	Subplots per acre[1]	
White oak	99	89
Hickory	56	53
Yellow-poplar	45	28
White ash	46	54
Post oak	35	34
Chestnut oak	22	19
Scarlet oak	23	22
Black cherry	18	12
Northern red oak	10	5
Black oak	11	14
Southern red oak	12	13
Blackjack oak	4	4
No desirable tree species present	54	88

[1]Numbers are based upon the tallest desirable stem in each of the 10- by 10-foot subplots. For example, white oak was the tallest desirable tree on 99 subplots per acre after 2 years.

Loblolly pine has been widely planted on the Plateau and Rim, usually following intensive site preparation. However, in recent years the high cost of site preparation has discouraged some owners from planting. The results of this study show that loblolly can be introduced into low-quality stands with little or no site preparation. However, the viability of this approach depends on the intensity of the harvest and the willingness of the owner to accept variable distribution of pines with a hardwood component.

The performance of the 5-year-old loblolly on the Cumberland Plateau study area is very encouraging in both injected and uninjected plots. The herbicide injection that reduced the number of residual stems from over 400 to about 30 per acre was considered reasonably effective. In plots where residual stems had been injected, 62 percent of the loblolly were judged completely free-to-grow and 84 percent were as tall as the competing hardwoods. In uninjected plots, only 32 percent of the loblolly were free-to-grow and 52 percent were as tall as the competition. Somewhat surprisingly, the percentage of dominant pines on the uninjected plots has continued to increase; an additional 13 percent outgrew the hardwood competition between years 4 and 5 (fig. 9).

While herbicide injection of residual hardwoods at the time of harvest was effective in increasing loblolly pine dominance on the Plateau, it is interesting that average heights of pine on injected plots vs. uninjected plots do not significantly differ after 5 years. However, there is greater uniformity in the loblolly pines in the injected plots, and eventually pine yields should be greater on these plots.

On the Western Highland Rim study area the planted loblolly received no release following the harvest of all trees whose d.b.h. was larger than 1 inch, and 36 percent were as tall or taller than the competing hardwoods after 3 years. Only 21 percent had been as tall as the competition after 2 years (fig. 13). Without further treatment many of the planted pines will never be dominant or codominant, but these pines have been introduced into the stand at no expense to the landowner except for planting costs. If the competing hardwoods were lopped after 3 years, loblolly would probably be dominant on 90 percent of the subplots after 5 years.

The selection of the best species to plant, the decision to accept natural regeneration, the determination of subsequent site preparation needs, and, certainly, the advisability of pine-hardwood mixtures are definitely subjects open to conjecture—depending on the objectives of management and specific conditions. However, it is very clear that, regardless of the pathway to regeneration, an intensive harvest of low-quality stands will make the pathway easier and less

expensive. Every tree that is used is one less tree that must be controlled or that will interfere with future stand development.

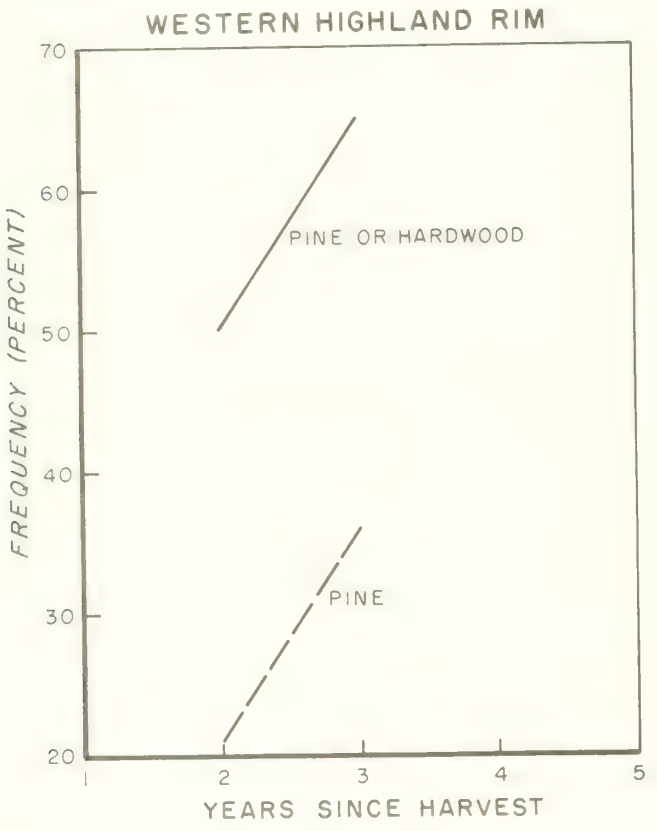

Figure 13.—*Frequency of pine or desirable hardwoods being the tallest tree on a 10- by 10-foot subplot.*

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APPENDIX

Common Names	Scientific Names
Ash, white	*Fraxinus americana* L.
Blackgum	*Nyssa sylvatica* Marsh.
Cherry, black	*Prunus serotina* Ehrh.
Dogwood	*Cornus florida* L.
Hickory	*Carya* spp.
Maple, red	*Acer rubrum* L.
Oak	*Quercus* spp.
black	*Q. velutina* Lam.
blackjack	*Q. marilandica* Muenchh.
chestnut	*Q. prinus* L.
northern red	*Q. rubra* L.
post	*Q. stellata* Wangenh.
scarlet	*Q. coccinea* Muenchh.
southern red	*Q. falcata* Michx.
white	*Q. alba* L.
Pine	*Pinus* spp.
loblolly	*P. taeda* L.
shortleaf	*P. echinata* Mill.
eastern white	*P. strobus* L.
Sassafras	*Sassafras albidum* (Nutt.) Nees
Sourwood	*Oxydendrum arboreum* (L.) DC
Yellow-poplar	*Liriodendron tulipifera* L.

Discussion of chemicals in this paper does not constitute a recommendation for their use or imply that uses discussed here are registered. If herbicides are handled, applied, or disposed of improperly, they can harm humans, domestic animals, desirable plants, pollinating insects, and fish or other wildlife. Water supplies can be contaminated. Herbicides should be used only when needed and handled with care. Directions on the container label should be followed and precautions heeded.

McGee, Charles E. Regeneration after shear felling and chipping of upland hardwoods. Res. Paper SO-224. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1986. 13 p.

Intensive utilization of low-quality hardwood stands is suggested as a way to reduce site preparation requirements and improve regeneration. The benefits and problems associated with limited site preparation and pine-hardwood mixture are discussed.

Additional keywords: Natural regeneration, planted pines, pine-hardwood mixture, intensive harvest, Cumberland Plateau, Western Highland Rim.

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**Southern Forest
Experiment Station**

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Research Paper
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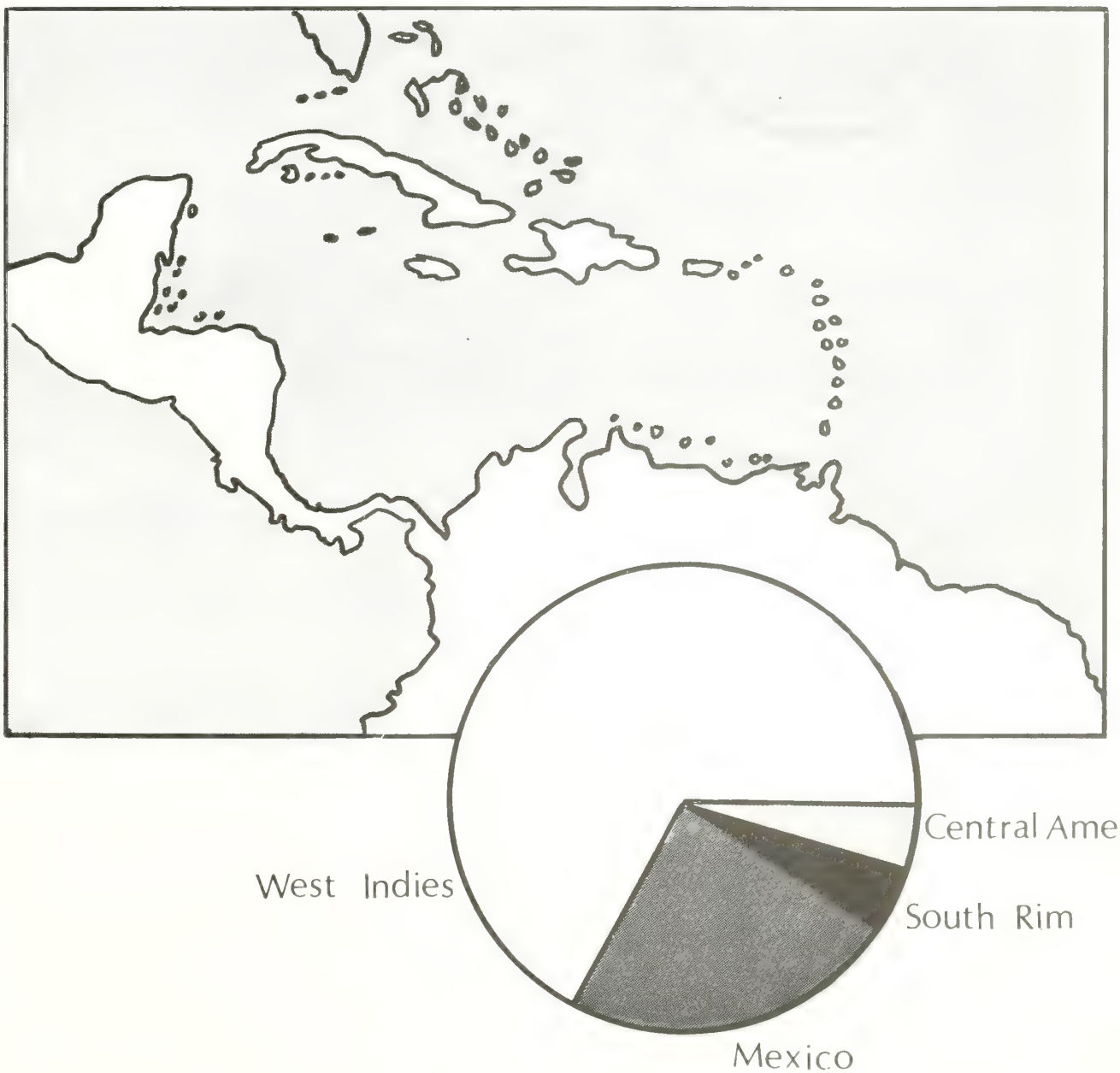
Caribbean Markets for U.S. Wood Products

Harold W. Wisdom, James E. Granskog, and Keith A. Blatner



SUMMARY

The West Indies and the continental countries bordering the Caribbean Sea constitute a significant market for U.S. wood products. In 1983, wood product exports to the region totaled almost $157 million. The Caribbean Basin primarily is a market for softwood products, with pine lumber being the most prominent item. The flow of exports to the region is dominated by (1) overseas shipments from southern ports to the West Indies and (2) overland shipments from the Southwestern United States to Mexico.

CONTENTS

INTRODUCTION 1
THE CARIBBEAN BASIN 1
Forests 1
Mexico 2
Central America 2
South Rim 3
West Indies 3
Wood Production and Trade 3
U.S. WOOD EXPORTS 4
Roundwood 5
Logs 5
Poles 5
Other 6
Lumber 6
Softwood 6
Hardwood 7
Treated 9
Crossties 9
Wood Panels 9
Veneer 9
Plywood 9
Particleboard 9
Miscellaneous Manufactured Products 9
DISCUSSION 10
LITERATURE CITED 12

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INTRODUCTION

As the U.S. wood products industry becomes more cognizant of marketing overseas, specific export markets are being scrutinized for potential development. One region attracting interest is the Caribbean Basin. Publicity generated by the recent "Caribbean Basin Initiative" has drawn attention to the area's potential for trade and development.

Despite the advantage of proximity, the Caribbean Basin has been overlooked relative to export markets such as Japan and Western Europe. Because most of the countries in the Caribbean Basin are small island nations, they do not frequently appear among the leading importers of U.S. wood products individually. Collectively, however, they constitute an important market. The West Indies, for instance, always has been a major buyer of southern pine lumber.

This report analyzes trends in U.S. wood exports to markets in the Caribbean Basin. Data on U.S. wood exports are from Bureau of the Census (U.S. Department of Commerce) computer tapes for 1967–83. Background information on wood production and trade in the Caribbean Basin was obtained from the "Yearbook of Forest Products" (Food and Agriculture Organization 1983).

THE CARIBBEAN BASIN

The Caribbean Basin includes the Caribbean island nations and the continental countries bordering the Caribbean Sea. For this report, the area is divided into four subregions: Mexico, Central America, the South Rim (the five South American countries bordering the Caribbean Sea), and the West Indies. Mexico is treated separately, because it dwarfs the other countries in size and population. Also, it is the only Caribbean nation with direct overland access to the United States, which influences the origin of U.S. exports to that country.

The Basin is an extremely diverse region consisting of a large number of countries that range widely in size, population, customs, and economic complexity. Reflecting its colonial history, the region is fragmented by four languages: English, French, Spanish, and Dutch. Its cultures also reflect the influence of Africa and the indigenous Indians. In a sense, the only common element that ties the countries together is the Caribbean Sea, which at the same time, isolates the countries and contributes to their differences.

The Basin has a total population of more than 167 million, scattered in some 30 countries and territories (table 1). Populations are growing, but per capita incomes are generally low. Many of the island economies are based largely upon a single industry, e.g., sugarcane or tourism, and were heavily impacted by oil price increases during the 1970's, which drained foreign exchange and severely limited economic growth. Although Mexico, Venezuela, and Trinidad benefited from oil exports, these countries also have been adversely affected by the more recent worldwide economic slowdown and falling oil prices.

Forests

The forests of the region are as diverse as the people and the economies. Because of steep topography and small size, most Caribbean islands support a wide variety of forest types that cover only small areas (Lugo and others 1981). Continental forests vary in composition from stands that are mostly pine in Central America to lush tropical rain forests in the South Rim that include hundreds of species. Despite the

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Table 1.—*Area, population, and gross national product of the Caribbean Basin, by region and country* [1]

Subregion/ country	Area	Population		Gross national product	
		Total	Growth	Total	Per capita
	Thou. sq. mi.	*Thousands*	*Percent*	*Billion U.S. $*	*U.S. $*
Mexico	761.6	69,400	2.7	162.0	2,335
Central America	197.1	24,323	.....	27.7	1,140
Belize	8.9	154	1.9	.2	1,300
Costa Rica	19.7	2,624	2.8	5.0	1,905
El Salvador	8.3	4,685	3.0	3.1	660
Guatemala	42.0	7,714	3.1	9.9	1,285
Honduras	43.3	4,276	3.6	2.8	655
Nicaragua	45.7	2,812	3.3	2.3	820
Panama	29.2	2,058	2.3	4.4	2,140
West Indies	91.3	30,655	.....	49.0	1,600
Bahamas	4.4	223	2.0	1.1	4,935
Barbados	.2	251	.3	1.0	3,985
Cayman Isles	.1	20	[2]	[2]	[2]
Cuba	44.2	9,858	1.2	10.0	1,015
Dominican Republic	18.8	6,248	2.4	6.7	1,070
East Caribbean[3]	2.3	1,196	1.3	3.3	2,760
Haiti	10.7	5,690	1.7	1.8	315
Jamaica	4.4	2,335	1.5	2.7	1,155
Netherland Ant.	.4	247	1.5	1.3	5,265
Puerto Rico	3.4	3,260	2.6	12.7	3,895
Trinidad/Tobago	2.0	1,211	1.3	8.4	6,935
Turks & Caicos Is.	.2	8	[2]	[2]	[2]
Virgin Isles - Brit.	.1	13	[2]	[2]	[2]
Virgin Isles - U.S.	.1	95	4.4	.6	6,315
South Rim	964.7	42,816	.....	105.2	2,455
Colombia	439.7	27,030	2.1	33.9	1,255
French Guiana	34.7	73	3.6	.2	2,740
Guyana	83.0	833	.7	.6	720
Suriname	55.2	363	− .5	1.1	3,030
Venezuela	352.1	14,517	2.9	69.4	4,780
Caribbean Basin	2,014.7	167,194	.....	343.9	2,055

[1]Population totals are U.S. State Department estimates for mid 1983. Population growth rates are average annual growth for 1972–82. GNP figures are for the latest year available, generally 1982 or 1983.

[2]Not available.

[3]The Eastern Caribbean includes the French West Indies (Guadeloupe and Martinique) and the other small islands of the Leeward and Windward Islands (Anquilla, Antiqua, Dominica, Grenada, Montserrat, St. Christopher-Nevis, St. Lucia, and St. Vincent and the Grenadines).

Sources: U.S. Department of State 1982–84, 1984.

many species that inhabit most areas of the region, however, relatively few are used commercially (Longwood 1962).

Forest areas have been reduced by population growth and associated agricultural and energy needs. Generally, the higher the population density, the lower the percentage of land area that is forested. Countries in the South Rim are the most extensively forested, and the West Indies are the least forested (table 2).

Mexico.—Mexico's forests have been heavily exploited for fuel and timber. Of the 44 million forested hectares, about two-thirds are in temperate-coniferous forests at higher elevations in the various mountain ranges, mostly in the northern States of Chihuahua and Durango (Caballero and others 1977). The remaining tropical forests are largely confined to the southeastern lowland and coastal plains.

Central America.—More than half the area of Central America is forested. Extensive tropical rain

Table 2.—*Forest areas of the Caribbean Basin*

Subregion	Total area	Percent forested
	Million hectares	
Mexico	202	22
Central America	50	56
South Rim	243	65
West Indies	24	18
Total	519	*45

*Weighted average.

Source: Lugo and others 1981, Caballero and others 1977.

forests along the eastern coast include the majority of the valuable woods, although species such as mahogany and Spanish cedar have been heavily cut. Pine stands in the mountainous interior of Honduras, Nicaragua, and Guatemala contain most of the remaining valuable softwood timber.

South Rim.—The South Rim contains some of the finest tropical hardwood forests in Latin America. Sparsely populated Guyana, Suriname, and French Guiana are mostly forested, but much of the area is inaccessible and timber exploitation is inhibited by the absence of a suitable transportation system. In more densely populated Colombia and Venezuela, substantial areas are being deforested annually for fuelwood and shifting agriculture. Venezuela, however, has implemented a softwood plantation program to reduce future import needs and to offset some of the forest loss.

West Indies.—The forests of the West Indies have been depleted through years of uncontrolled exploitation for charcoal, fuelwood, and clearing for agriculture. The two largest countries, the Dominican Republic and Cuba, still have sizeable forested areas but currently import substantial volumes of forest products. As a result of water problems that developed following deforestation in neighboring Haiti, timber cutting in the Dominican Republic has been restricted for the protection of watersheds. Jamaica and Trinidad-Tobago have active forestry programs, but their forest resources will not supply a substantial portion of domestic demand, at least for the foreseeable future. Forested areas also exist on most of the small islands, but they have little importance for commercial wood products.

Wood Production and Trade

The 1981 timber harvest in the Basin exceeded 3.6 billion cubic feet, or roughly one-fourth of the U.S. annual harvest. However, most of the Caribbean timber harvest was used for fuel—5 of every 6 cubic feet of harvested timber (table 3). Of the four subregions, only in Mexico did the harvest for industrial products exceed that for fuelwood. Furthermore, removals for

Table 3.—*Timber harvest in the Caribbean Basin, 1981*

Subregion	Fuelwood & charcoal	Industrial roundwood	Total
	Million cubic feet		
Mexico	212.8	224.1	436.9
Central America	865.4	134.0	999.4
South Rim	1,749.7	149.8	1,899.5
West Indies	280.0	29.9	309.9
Total	3,107.9	537.8	3,645.7

Source: FAO 1983.

fuelwood and charcoal have increased faster than for industrial products, 2.6 percent compared to 1.9 percent since 1967.

The pattern of heavy fuelwood use reflects rapidly growing populations and low per capita incomes, with forest use being dominated by shifting agriculture and energy needs. Construction practices and market structure are also factors in the low industrial roundwood harvest. Concrete is the preferred housing construction material in the Caribbean Basin. Economically, many of the small island nations do not have a population large enough to consume manufactured products in sufficient quantities to support domestic production. Even in the larger countries having sizeable populations and forest resources, lack of financing has been an obstacle to capital-intensive manufacturing, such as pulp and paper production.

Seventy percent of the 1981 industrial roundwood harvest was sawlogs and veneer logs, used primarily for the production of lumber and wood panels; most of the remainder, largely in Mexico, was used for pulp and paper production. Only a small amount of roundwood enters trade, mainly hardwood log exports from French Guiana, Guyana, and Suriname.

Sawnwood—lumber and crossties—is the principal wood product in the Caribbean Basin (table 4). Mex-

Table 4.—*Production of sawnwood and wood panels in the Caribbean Basin, 1981*

Commodity	Mexico	Central America	South Rim	West Indies	Total
	Million cubic feet				
Sawnwood					
Softwood	51.1	28.2	1.1	.7	81.1
Hardwood	2.8	31.4	50.7	4.8	89.7
Crossties	14.2	.8	1.5	.9	17.4
Total, sawn	68.1	60.4	53.3	6.4	188.2
Wood panels					
Plywood	10.5	2.3	3.0	.1	15.9
Particleboard	11.8	1.1	2.9	.3	16.1
Other	1.4	1.3	1.4	.5	4.6
Total, panels	23.7	4.7	7.3	.9	36.6

Source: FAO 1983.

ico, Honduras, and Nicaragua are the major softwood lumber producers, while Costa Rica, Nicaragua, and countries in the South Rim dominate hardwood lumber production. Although hardwood lumber production in Mexico is small, crosstie output is substantial. Mexico also accounts for about two-thirds of the region's production of wood panel products.

Both softwood and hardwood lumber production have declined since 1977, after increasing slightly during the prior decade (fig. 1). The softwood decline has been more severe as production has fallen in each of the three major producing countries, where the most accessible pine stands have been harvested. Also, economic and political conditions have impacted production and, more importantly, trade.

The Basin is a net importer of softwood lumber, and its deficit has widened (fig. 2). The West Indies is the major importer, but rapid growth in Mexico and Venezuela in the late 1970's also spurred imports. During the same period, shipments from the region's exporters—Honduras and Nicaragua—were falling, creating a growing market for outside suppliers. Exports from Honduras have dropped since nationalization of its forest products industry in 1974, and political unrest has disrupted the flow of lumber from Nicaragua.

Since hardwood resources are more dispersed than softwood, the hardwood lumber trade is much smaller; however, imports have been exceeding exports by a growing margin since 1976. The South Rim is the leading hardwood exporter, followed by Central America. The West Indies is the dominant importer.

The Basin also is a net importer of panel products (fig. 3). Imports have grown despite an overall expansion in regional production. Most of the increase in panel production occurred in Mexico, where it is used internally, while increasing consumption in the rest of the region is being met by imports. Costa Rica and Suriname are the main panel exporters, and Mexico and the West Indies account for most of the panel imports.

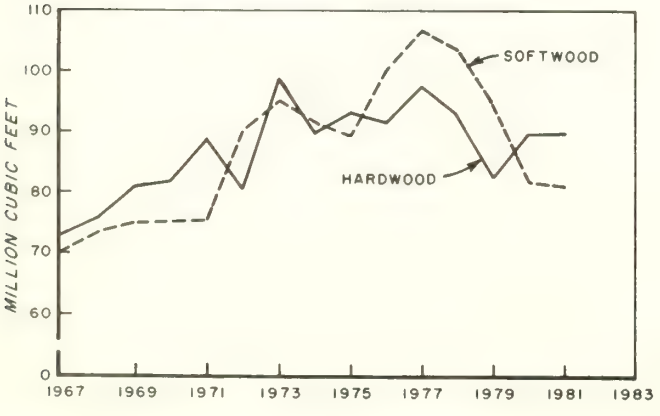

Figure 1.—*Lumber production in the Caribbean Basin, 1967–81.*

U.S. WOOD EXPORTS

U.S. exports of wood products—roundwood, lumber, wood-based panels, and miscellaneous manufactured products—to the Caribbean Basin were valued at $157 million in 1983. Shipments to the region climbed from $26 million in 1967 to $211 million in 1981, before declining in 1982 and 1983 as a result of foreign debt problems in Mexico and Venezuela.

The value of shipments by product and country of destination for 1983 is detailed in table 5. Lumber was the most important export item, accounting for $86 million, or 56 percent of the total. Lumber also has accounted for the largest portion of the increase in wood exports to the Caribbean Basin since 1967 (fig. 4).

Almost one-third of all wood exports to the Caribbean Basin consist of miscellaneous manufactured wood articles. The importance of this group reflects modest demands for a large variety of secondary products, which add up to a significant portion of the total value.

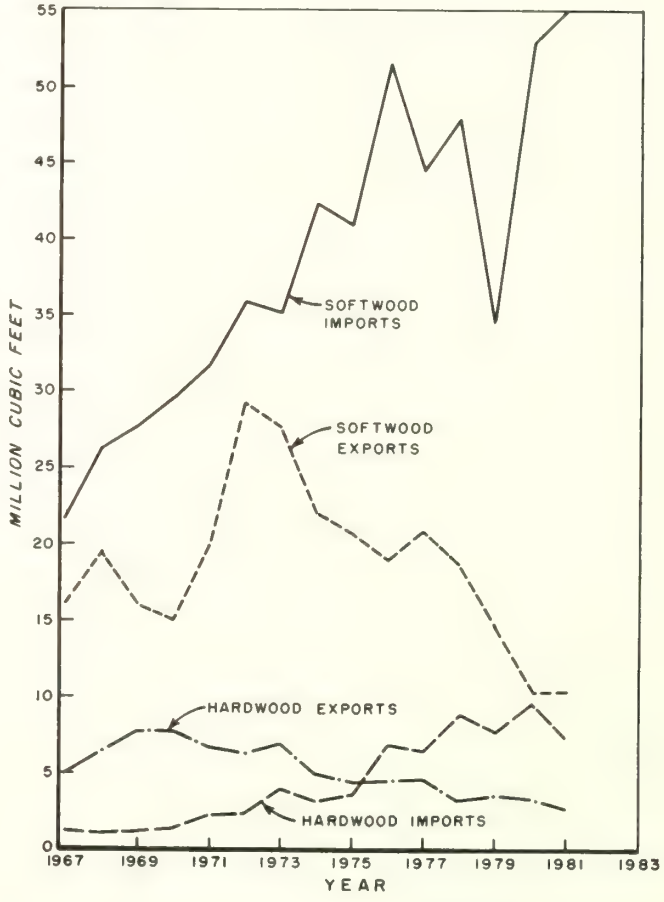

Figure 2.—*Lumber trade in the Caribbean Basin, 1967–81.*

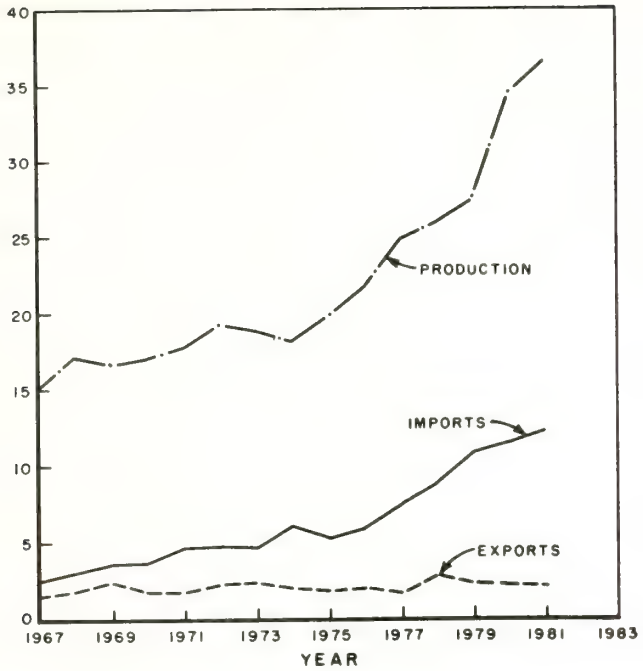

Figure 3.—*Panel production and trade in the Caribbean Basin, 1967–81.*

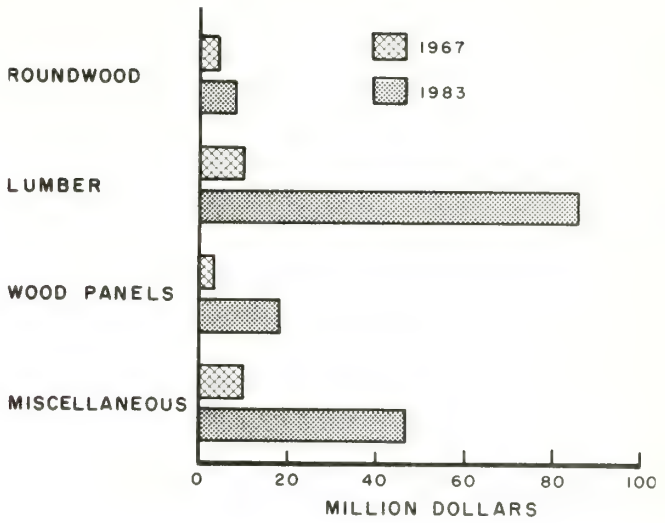

Figure 4.—*Wood exports to the Caribbean Basin by product group, 1967 and 1983.*

Currently, the West Indies is the largest of the four regional markets (fig. 5). Exports to Mexico, the primary market before 1982, declined sharply in 1982 and 1983, reflecting its economic problems. The West Indies was the only Caribbean Basin market that continued to grow during 1981-83.

As a practical matter, the pattern of U.S. exports to the Caribbean Basin can be described as (1) overland shipments from the Southwest to Mexico and (2) overseas shipments from southern ports to other Caribbean markets (table 6). In 1983, 91 percent of wood exports to Mexico were overland shipments from southwestern customs districts, and Mexico also accounted for 92 percent of all western U.S. wood exports to the Caribbean Basin. In contrast, southern ports provide 90 percent of the exports to the West Indies, the South Rim, and Central America. Also, exports from Puerto Rico are largely southern in origin.[1]

Roundwood

Logs.—The U.S. exports only a modest amount of logs to the Caribbean Basin. In 1983, log exports amounted to only 2.5 million board feet, valued at $1.5 million. This was a sharp decline from the 1980 peak of 9.1 million board feet, but still above the 1.5 million board feet exported in 1967. The decline since 1980 has been due to a sharp reduction in softwood log exports, although hardwood log exports also declined.

Softwoods have averaged 64 percent of total log exports since 1980. Walnut and oak logs, used in the manufacture of furniture and millwork, are the principal hardwood species exported.

Mexico and the South Rim are the most important log markets, each absorbing one-third of total U.S. log exports to the Caribbean Basin in 1981-83. The West Indies is third in importance, followed by Central America. Venezuela is the principal South Rim market.

Poles.—The Caribbean Basin is more important as a market for poles than it is for logs. U.S. pole exports to the Basin in 1983 were valued at $4.3 million. Utility poles made up 85 percent of the value of pole shipments; the remainder was short poles and posts less than 15 feet in length.

About 60,000 utility poles are exported to the Caribbean Basin annually. The level of pole exports has not changed appreciably since 1967, although it has fluctuated widely from year to year (fig. 6).

Most poles are imported by government-owned utilities. With few exceptions, electric power and telephone service in the Caribbean Basin are distributed by lines strung overhead on poles. Pole exports to the Basin reflect the expansion of power and telephone distribution systems and the replacement of old poles. Outside of those countries having pine resources, few local trees are of sufficient height, form, and durability to be used as utility poles.

[1]Although Puerto Rico is within the Caribbean Basin, it also is a possession of the United States. Shipments to Puerto Rico from the United States are not counted as U.S. exports; however, shipments from Puerto Rico to other countries are included in U.S. export statistics. For a description of U.S. shipments of wood products to Puerto Rico, see Wisdom and others (1983).

Table 5.—*Value of U.S. wood exports to the Caribbean Basin, 1983*

Subregion and country	Roundwood	Lumber	Panels	Misc.	Total
			Thousand dollars		
Mexico	884	21,909	3,344	12,199	38,336
Central America					
Panama	683	1,523	224	485	2,924
Belize	.....	.....	158	731	889
El Salvador	141	.....	24	527	692
Honduras	1	7	64	440	512
Guatemala	.....	.....	24	200	224
Costa Rica	67	.....	4	149	220
Nicaragua	.....	8	.....	65	73
Total	892	1,547	498	2,597	5,534
West Indies					
Bahamas	291	6,186	2,693	11,715	20,885
Bermuda[1]	78	926	202	1,506	2,712
Jamaica	1,379	8,726	1,117	2,073	13,295
Cayman Isles	30	1,437	780	2,189	4,436
Haiti	700	2,608	457	1,060	4,825
Dom. Republic	225	14,534	2,049	1,208	18,016
LW, WW Isles	180	4,220	1,024	1,713	7,137
Barbados	588	3,560	288	470	4,906
Trinidad & Tobago	315	12,775	3,821	4,161	21,072
Neth. Antilles	142	5,135	1,079	1,594	7,950
French W. Indies	.....	472	42	183	697
Total	3,928	60,579	13,552	27,872	105,931
South Rim					
Colombia	.....	1,604	75	2,220	3,899
Venezuela	15	551	59	1,922	2,558
French Guiana	.....	4	1	167	171
Guyana	.....	3	2	158	163
Suriname	2	.....	.....	48	49
Total	17	2,162	137	4,526	6,842
Caribbean Basin	5,721	86,197	17,531	47,194	156,643

[1]Although not located in the Caribbean Basin, Bermuda traditionally is grouped with the West Indies in trade statistics.

Mexico, Central America, and the West Indies have exchanged positions of relative importance several times since 1967, with no discernable trend in any market. Based upon the average for the years 1981-83, the largest individual markets are Panama, Mexico, Jamaica, Dominican Republic, Haiti, and Venezuela. Shipments to the major markets are highly unstable.

About 900,000 short poles are exported to the Caribbean Basin annually (table 7). Mexico is the largest buyer, followed by Guatemala.

Other.—Small and irregular quantities of pulpwood, wood chips, and other rough wood are exported to the Caribbean Basin. Mexico is normally the main market for these products, although two shiploads of wood chips were exported to Venezuela in the late 1970's (Granskog 1982).

Lumber

Softwood exports dominate U.S. lumber shipments to the Caribbean Basin. Of the $86 million in lumber exports in 1983, 83 percent was softwood lumber; the remainder was equally divided between hardwood lumber and crosstie shipments.

Softwood.—Softwood lumber is the most important U.S. wood export to the Caribbean Basin, typically accounting for almost one-half the value of all wood product shipments. Pine lumber is preferred—three-fourths of the softwood shipments have been southern pine and ponderosa and other western pines. Douglas-fir and redwood are most notable among the remaining softwood exports.

Trends and markets for softwood lumber exports to the Basin are best illustrated by grouping the ship-

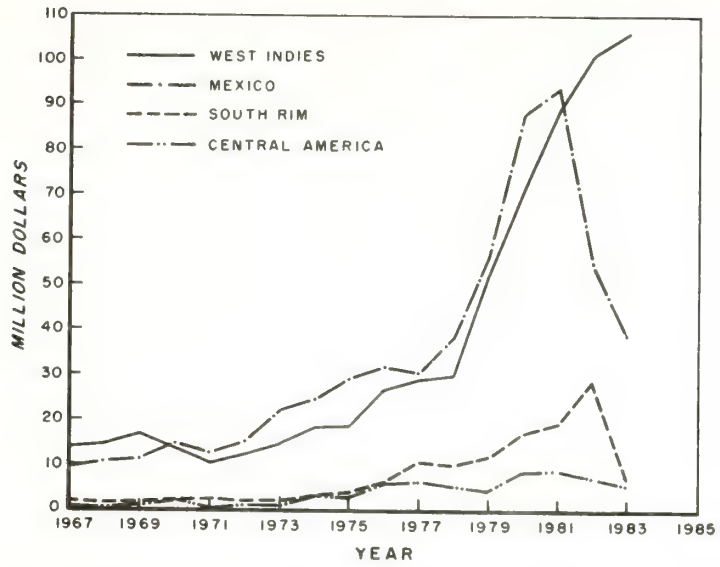

Figure 5.—*Exports to the Caribbean Basin, by market, 1967–83.*

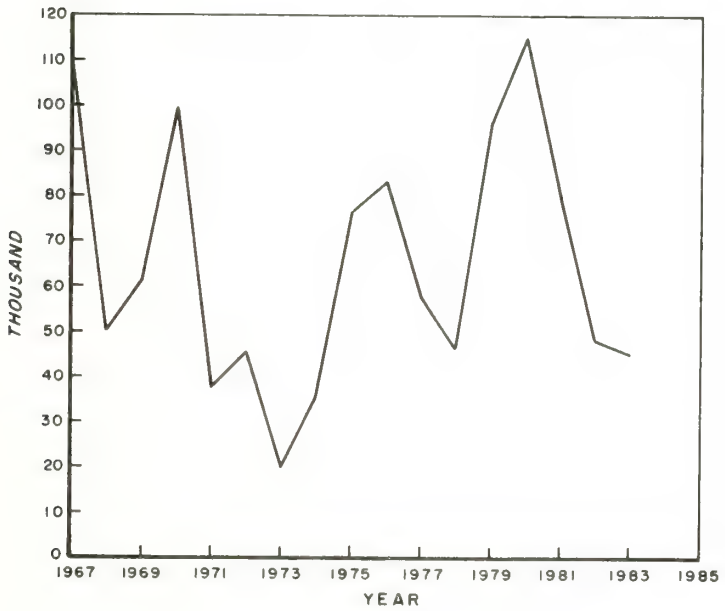

Figure 6.—*Utility pole exports to the Caribbean Basin, 1967–83.*

ments into two categories—southern pine and other softwood (figs. 7 and 8). Most southern pine is shipped to the West Indies, while the majority of the other softwood is exported to Mexico. These two markets were largely responsible for the rapid increase in exports of both softwood groups in 1978-81, when total shipments surged from 130 million to 353 million board feet. However, Venezuela also became a significant buyer of southern pine in 1980-82. The sharp decline of other softwood shipments in 1982 and 1983 stemmed from economic problems in Mexico; the smaller drop in southern pine exports in 1983 was caused by import restrictions in Venezuela, as shipments to the West Indies continued to increase. As a result, southern pine's share of the softwood lumber exports increased from 28 percent in 1967 to 60 percent in 1983.

Traditionally, the Caribbean Basin markets have purchased dressed lumber. In 1967, 95 percent of all southern pine and 74 percent of all other softwood shipped to the Caribbean Basin was dressed lumber. In recent years, however, rough lumber has been increasing its share of the market, to 40 percent of the southern pine and 38 percent of the other softwood lumber exported in 1983.

Hardwood.—U.S. exports of hardwood lumber to

Table 6.—*The value of U.S. wood exports to the Caribbean Basin, by customs district, 1967 and 1983*

Customs district	1967	1983
	---- *Thousand dollars* ----	
South		
Charleston, SC	62	3,249
Savannah, GA	455	14,759
Miami, FL	7,731	44,864
Tampa, FL	2,132	4,129
Mobile, AL	2,320	37,075
New Orleans, LA	1,226	1,555
Other South	126	1,069
Total, South	14,052	106,700
West		
Laredo, TX	2,583	4,039
El Paso, TX	1,078	9,998
Nogales, AZ	844	2,259
San Diego, CA	4,236	18,636
Other West	936	6,626
Total, West	9,677	41,558
Puerto Rico	24	5,933
Other	2,200	2,451

Table 7.—*Short pole exports to the Caribbean Basin, average for 1981–83*

Market	Number of poles
Mexico	394,067
Guatemala	141,700
Honduras	86,000
Bahamas	70,624
Dominican Republic	53,378
Haiti	29,518
Netherlands Antilles	26,096
Venezuela	24,866
Trinidad & Tobago	22,700
Other	54,026
Total	902,975

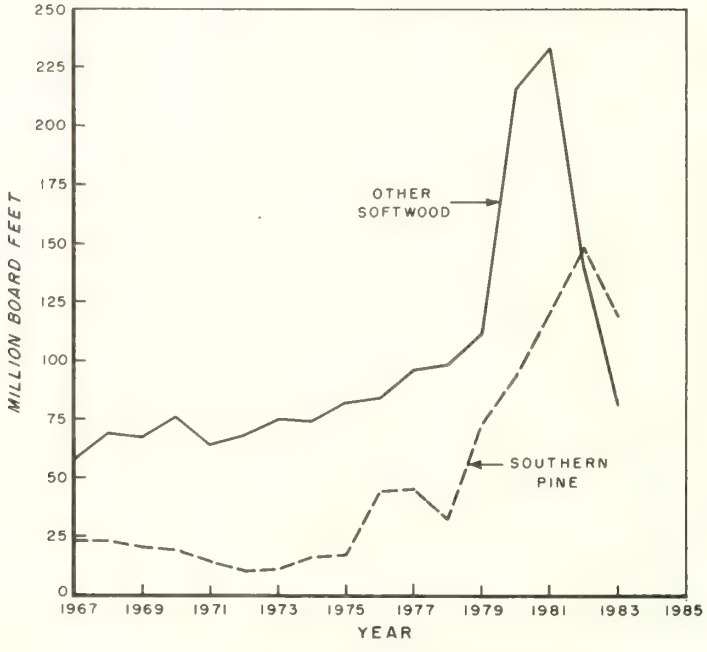

Figure 7.—*Softwood lumber exports to the Caribbean Basin, 1967–83.*

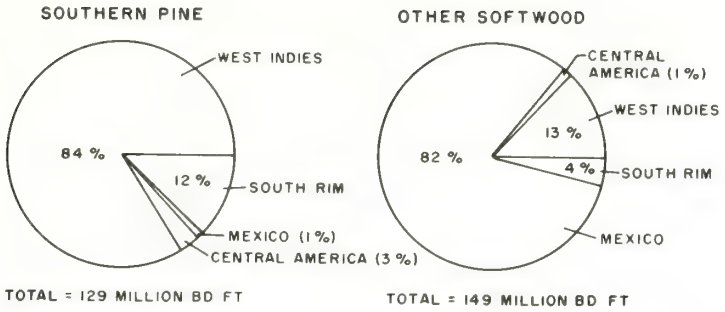

Figure 8.—*Softwood lumber markets in the Caribbean Basin, average for 1981–83.*

the Caribbean Basin have averaged about 15 million board feet since 1980. Although modest, this level of shipment is roughly three times the volume exported in 1967. Mexico absorbs about three-quarters of the hardwood lumber and has accounted for most of the growth in hardwood lumber exports to the region; the remainder largely goes to the West Indies.

Unlike other foreign markets, where shipments of oak dominate U.S. hardwood lumber exports, most shipments to the Caribbean are in the "other hardwood" category. Although oaks make up the largest volume that is identified by species, they usually account for only 10 to 15 percent of total shipments.

Treated.—Treated lumber has been identified in the export classification system since 1978. Census data indicate that shipments to the Caribbean Basin reached a high of 7.1 million board feet in 1980 before declining to about 2 million board feet in 1982-83. However, market reports prepared by the Southern Forest Products Association for the Caribbean generally indicate a significant proportion of southern pine shipments—perhaps 20 to 30 percent—is treated lumber (SFPA 1981, 1982a, 1982b). If so, export statistics do not fully reflect the actual level of treated lumber shipments to the Caribbean area. In any case, the West Indies appears to absorb the bulk of the volume.

Crossties.—Crosstie exports to Caribbean markets have fluctuated widely, with shipments in recent years often exceeding the levels of hardwood lumber exported to the region. After a high of 29 million board feet in 1980, crosstie exports declined to 7 million feet in 1982 and then rose again to 18.6 million feet in 1983. Mexico is the largest market and has accounted for much of the fluctuation. Other markets are Panama, Venezuela, and, in the West Indies, the Dominican Republic and Jamaica—the only islands with railway systems. Colombia also became a significant market in 1983, due to construction of a railroad associated with the large Cerrejon Coal Project in that country.

Crosstie exports to the Caribbean are predominantly treated hardwood, although softwood ties have made up a majority of recent shipments to Mexico.

Wood Panels

The United States exported $18 million in wood panel products in 1983. Plywood accounted for 82 percent of the value; particleboard, 13 percent; and veneer, 5 percent.

Veneer.—Almost 15 million square feet of veneer was exported to the Caribbean Basin in 1983. Hardwoods amounted to 12 million square feet, or four-fifths of total veneer exports (fig. 9). Hardwoods traditionally have dominated, except during 1980-81 when softwood veneers—mostly reinforced or backed—led a surge of veneer shipments to Mexico. Exports to Mexico plummeted in 1982 and 1983, reflecting its foreign debt problems.

Plywood.—About 52 million square feet of plywood was exported to the Caribbean Basin in 1983. Both softwood and hardwood plywood exports have increased in recent years (fig. 10).

The West Indies absorbed three-fourths of the hardwood plywood and four-fifths of the softwood plywood exports in 1983. The Bahamas and Trinidad-Tobago were the largest markets in the West Indies, followed by the Dominican Republic, the Cayman Islands, and Jamaica. Central America and the South Rim account for only a minor portion of either hardwood or softwood plywood exports.

Shipments in the "other" category are primarily cellular panels, sandwich-type assemblies with plywood sheets bonded to both sides of a core material.

Particleboard.—Since 1979, particleboard exports have averaged about 21 million square feet, with an annual value of about $5 million (table 8). Mexico has absorbed the bulk of the particleboard shipments, although Venezuela in the South Rim also was a significant market in the late 1970's.

Miscellaneous Manufactured Products

A wide variety of miscellaneous articles of wood are exported to countries throughout the Caribbean Basin. Generally products of secondary manufacturing, these articles are grouped in the categories shown in table 9. Because there is no common measure of

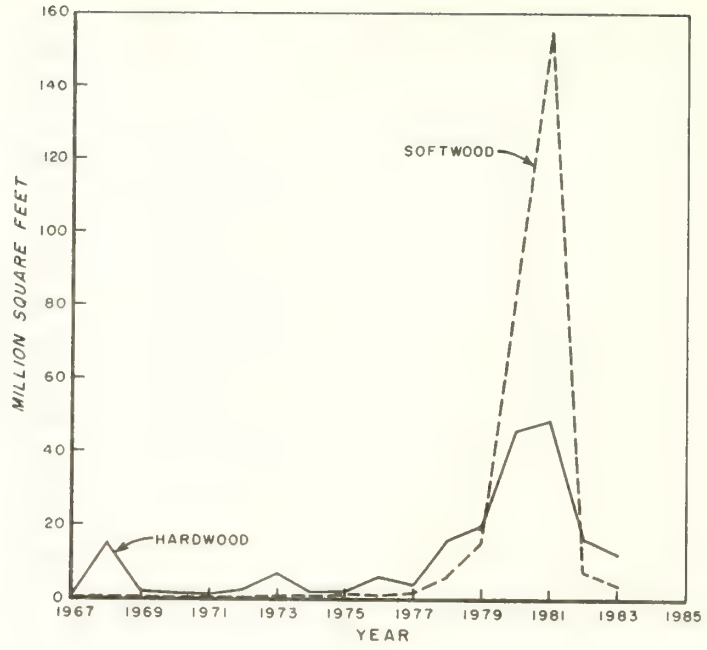

Figure 9.—*Veneer exports to the Caribbean Basin, by species, 1967–83.*

volume, they are shown in terms of value only; however, the deflated 1983 figures indicate whether or not real growth occurred.

Prefabricated wood structures gained the most and now make up one-fourth of the total value of miscellaneous wood exports. Cooperage, once a major item, declined in importance from 15 percent of the total in 1967 to only 2 percent in 1983. The composition of miscellaneous wood exports also became more diversified after 1967, as reflected in the increase in the "other" category from 40 percent in 1967 to 58 percent in 1983.

The West Indies and Mexico have been the most important markets for miscellaneous wood articles, accounting for 59 and 26 percent of total exports in 1983 (fig. 11). Although shipments to Central America and the South Rim have been smaller, products in this group are the most important wood export to these markets.

DISCUSSION

Despite recent declines in shipments to Mexico and Venezuela, U.S. wood product exports to the Caribbean Basin increased from $26 million in 1967 to $157 million in 1983. A large portion of the increase was due to rising exports of softwood lumber, as U.S. shippers benefited from declining exports from Central America to the West Indies over the past decade.

Future U.S. wood shipments to Caribbean markets will depend in large part on the rate of economic progress in the area, the actions of competing softwood suppliers, and whether exporting programs are designed to meet the unique characteristics of the market. Although per capita incomes are relatively low in the Basin countries, rapidly expanding populations are generating housing needs that support continuing imports necessitated by the lack of domestic softwood resources. Political instability in Central America has disrupted the flow of softwood lumber from that area, but Honduras—the largest competitor—is ex-

Table 8.—*U.S. particleboard exports to the Caribbean Basin, by market, 1967–83*

Year	Total	Mexico	Central America	West Indies	South Rim
	Thousand square feet				
1967	448	235	54	159	0
1968	544	391	12	141	0
1969	658	541	0	117	0
1970	521	388	0	123	10
1971	764	657	15	92	0
1972	1,078	661	5	412	0
1973	2,846	2,442	168	236	0
1974	13,148	12,583	251	310	4
1975	4,803	4,027	208	498	70
1976	11,894	8,588	163	1,253	1,890
1977	23,261	11,199	74	1,661	10,327
1978[1]	16,721	9,987	88	3,109	3,537
1979	31,485	21,015	620	4,422	5,428
1980	34,566	24,957	261	4,459	4,889
1981	28,115	22,844	356	4,679	236
1982	17,188	14,262	58	2,642	226
1983	5,901	3,002	192	2,679	28

[1]1978 data are estimates. Bureau of Census figures contain reporting errors, due to a change in the unit of measurement.

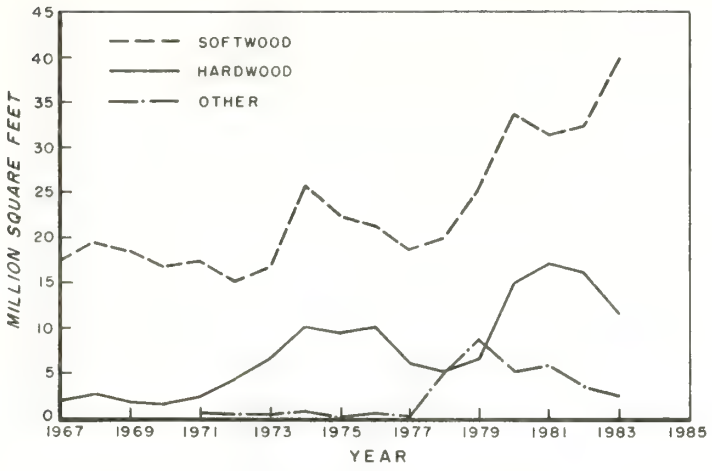

Figure 10.—*Plywood exports to the Caribbean Basin, by type, 1967–83.*

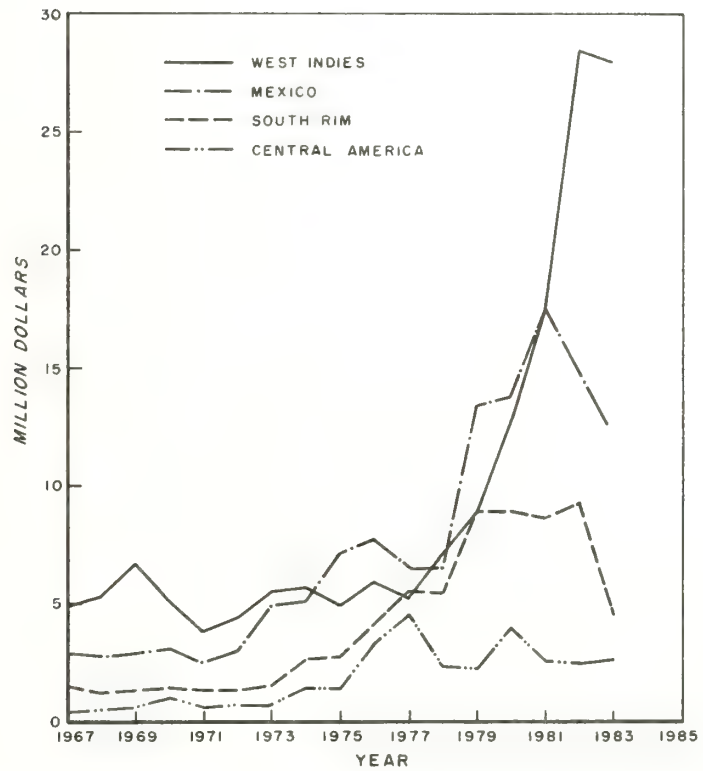

Figure 11.—*Miscellaneous exports to the Caribbean Basin, by market, 1967–83.*

Table 9.—*U.S. exports of miscellaneous manufactured wood articles to the Caribbean Basin, by type, 1967 and 1983*

Type	1967	1983	Deflated* 1983
		Thousand dollars	
Fuelwood & charcoal	264	977	322
Cooperage	1,544	833	275
Builder's woodwork	2,567	4,710	1,554
Prefab. wood structures	465	11,830	3,903
Decorative wood articles	326	466	154
Wood handles	711	1,192	393
Other	3,850	27,186	8,969
Total	9,727	47,194	15,570

*Deflated using Producer Price Indexes for Wood Products, 1967 = 100.

panding its sawmilling capacity. Also, Chile has been a recent supplier of Radiata pine lumber in the region. Thus, maintaining or expanding U.S. shipments will require aggressive and innovative marketing efforts.

A key to effective marketing in the Basin is an understanding of the economics of the region. Although the market is quite large when viewed as a whole, the individual economies are quite small and extremely diversified in terms of purchasing habits, traditions, and preferences. At any one time, some countries may be experiencing economic expansion while others are undergoing economic stress. As a result, the demand for a specific product may exhibit substantial fluctuation when viewed on a country-by-country basis. Exporters must be aware of this demand situation and continuously monitor the markets in individual countries.

Continuity of supply is an important factor in serving the Caribbean Basin. Though concrete is the preferred housing material, softwood lumber and plywood are used for scaffolding, concrete forms, and roof structures. Although wood comprises only a small portion of the total cost of housing, it is still an essential ingredient in construction. Lacking capital, building material suppliers typically maintain limited inventories; hence, they make small orders frequently. Because virtually all the wood used in construction in the West Indies must be obtained by ocean carrier, taking 2 to 6 weeks for delivery, failure to receive an order when scheduled may result in construction delays and thus be more costly than the extra cost of wood from a more dependable source. Under these circumstances, reliability of supply can be more important than price when choosing among suppliers.

Caribbean wood importers also typically place orders for a wide mix of products, reflecting the Basin's dependence upon imports for much of its needs. Wood exporters must be willing to supply a variety of wood products in different sizes, grades, and species. This is an obstacle for many U.S. softwood producers, who are used to manufacturing a few commodity items for domestic markets rather than specialty items for overseas markets. On the other hand, softwood suppliers from other countries are often organized for export marketing, i.e., the production from several manufacturers is combined to meet the more diverse foreign demand.

A strategy for effectively serving the Caribbean market may be a cooperative effort. One approach is to establish regional export trading companies, as authorized by the Export Trading Company (ETC) Act of 1982. The ETC Act allows small- and medium-size companies the option to jointly supply a wider range of products to overseas markets. Also, an ETC can provide foreign purchasers an image of stability that a small, lone exporter may not possess.

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U.S. exports of wood products to four Caribbean markets—Mexico, Central America, the South Rim (South American countries bordering the Caribbean Sea), and the West Indies—are described for the years 1967 through 1983.

Additional Keywords: Wood exports, foreign trade, forest products.

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Using Hardwood Lumber With Insect, Fungus, and Bird Defects as Character-Marked Woods

J. D. Solomon

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SUMMARY

Insects, fungi, and birds cause defects in hardwoods that seriously degrade lumber cut from infested trees. Mills, burdened with an abundance of low-grade hardwoods, need a profitable outlet for this defective lumber. Much of this downgraded lumber could be used to manufacture decorative products such as paneling, selected furniture pieces, cabinets, picture frames, and other attractive items. Wormy chestnut and pecky cypress have been readily accepted as character-marked woods and are currently in demand. Flagworm defects in maple, sycamore, and white oak; spotworm, pinhole, and timberworm in oaks; pith flecks and streaks in maple, birch, black cherry, and ash; and bird peck in pecan and hickory can make very attractive character-marked woods. Large wormhole defects, because of their size, might be considered unacceptable in character-marked woods, but medium-sized defects, especially in ash and pecan, should be very acceptable. Some of these character-marked woods could be marketed separately, whereas others might be combined to facilitate handling, sorting, accumulating, and utilizing the material. Landowners, timber buyers, loggers, and mill personnel could be trained to recognize standing timber, logs, and lumber with character-marked values. Hardwood manufacturers need to recognize the opportunities for making use of these defects.

Using Hardwood Lumber With Insect, Fungus, and Bird Defects as Character-Marked Woods

J. D. Solomon

INTRODUCTION

Defects in hardwood trees increase the amount of degrade in sawn lumber and lower the market value of the product. Insect borers, next to growth malfunctions, are the major cause of defects that downgrade hardwood logs and lumber (Bryan 1960). Wormholes and bark pockets cause degrade in oaks amounting to $21/Mbf (wholesale price, rough-sawn) in the South (Morris 1977) and $24/Mbf in the Northeast (Donley and Worley 1976). Updated to current dollar values, these average losses just about double to $45/Mbf, representing an annual loss of $90 million in the 2 billion board feet of oaks cut annually (U.S. Department of Commerce 1985) in the Eastern United States.

Some mills have their yards full of defective, low-grade lumber—how to market or utilize this lumber at a profit presents an enormous problem (Elder 1976, Staples 1983). Although there is no shortage of hardwoods, a disproportionate amount of lower grade lumber is produced. Marketing the clear top grades is no problem; however, many producers have asked how they can profitably dispose of the lower grades.

Currently, most of the low-grade lumber ends up as flooring oak, railroad ties, pallet stock, pulp chips, and energy sources. A recent symposium addressed the problem of expanded utilization of low-grade hardwoods (Stumbo 1981). One promising new approach consists of harvesting small-diameter, low-grade trees as bolts and converting the wood to hardwood blanks for the furniture market (Gatchell and Reynolds 1981). Another approach involves separating character-marked stock and marketing it for decorative uses. A few companies are already accumulating character-marked wood during the handling, separating, sorting, and reworking process. For example, one company puts aside any character-marked stock, kiln dries it, saws it for wall paneling, and sells it at a handsome price (Elder 1976).

In view of the abundance of low-grade lumber and the tremendous problems associated with handling, marketing, and disposing of the lower grades, the industry needs to change its attitude and approach toward this problem. Instead of calling wormholes defects, many could be termed character marks. Why can't Character Grades be established? Instead of downgrading wormy lumber, why not place it in special Character or Decorative Grades? Doing so would upgrade the lumber after sorting and at the same time give the consuming public a natural, "never duplicated" character-marked product with exceptional beauty. Many people are familiar with the beauty, as well as demand and price, of wormy chestnut and pecky cypress. Papers have been written promoting "flagworm defect" in soft maple (Nord 1971), "grease spot defect" in oak (Morris 1964), and "wormhole defect" in pine (Applefield 1983, Levi 1978, Westbrook and others 1981) as character marks. In addition to these, about a dozen other kinds of wood with insect defects might fit into decorative grades.

Efforts have been made, particularly in recent years, to call attention to character-marked woods (mostly growth-type defects) and to promote their acceptance and use. The Fine Hardwoods-American Walnut Association (FHAWA) and the Hardwood Plywood Manufacturers Association (HPMA) have sponsored showings of character-marked woods (Southern Lumberman 1976). In 1978 the FHAWA held a series of seminars for furniture manufacturers, furniture designers, buyers, and sales representatives (Southern Lumberman 1978c). The FHAWA also built a mobile "Selectorama Showroom" to exhibit and display character-marked woods on the road (Southern Lumberman 1978d, 1979a). The Appalachian Hardwood Manufacturers, Inc., has developed "Appalachian Rustic Oak," a grade of red and white oak that contains sound knots, bird-pecks, some wormholes, and other character marks that add beauty and interest (Southern Lumberman 1978b).

Several opinion polls involving character-marked hardwoods conducted recently by the FHAWA in cooperation with the HPMA indicate a preference for character-marked woods as opposed to other grades (Southern Lumberman 1978a). In one survey, 62 percent of 4,398 families favored furniture made from character-marked woods.

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Although promotional work by trade associations includes some reference to defects, their major emphasis has been on the use of growth-type defects as character marks. The purpose of this paper is to promote insect borer defect, and to a lesser extent fungus and bird peck defects, as character marks, to point out opportunities for utilizing these character-marked woods, and to show how their utilization might add to and complement the growth defect character-marked wood already being emphasized and promoted.

METHODS

Information reported in this paper came from a study conducted between 1978 and 1985, primarily in the Southern and Southeastern States and to a lesser extent in other areas of the Eastern United States. Visits to selected mills, contacts with wood technologists and other utilization personnel, and discussions with hardwood foresters and managers in industry, National Forests, State and Private Forestry, and State Forestry Commissions provided information on the extent and seriousness of the problem of profitably utilizing the abundance of defective low-grade hardwoods. A review of the literature provided information on recent efforts by the hardwood manufacturers' associations to promote character-marked hardwoods.

Samples of wood, primarily lumber and veneer, containing various kinds of insect, fungus, and bird peck defects were collected from sawmills and veneer mills in Arkansas, Louisiana, Mississippi, Alabama, Georgia, North Carolina, and Tennessee. A few samples were obtained from mills in Minnesota, Wisconsin, Michigan, Ohio, and Pennsylvania. Assistance by several foresters and utilization specialists was helpful in assembling wood samples having various types of defect.

The various types of defect/character marks were characterized and described. For each kind of insect-caused defect, both the host tree species and the insect species responsible for the defect were identified. The nature of each defect was described including the presence or absence of wormholes, pith ray flecks and streaks, pockets of ingrown bark and gum, stains, and decay. The prevalence, number, size, shape, color, and arrangement or pattern of character marks in the wood were also described. Photos were taken of lumber containing defects to illustrate the appearance and beauty of each kind of character mark viewed as decorative paneling.

Discussions with numerous foresters and mill operators provided information on the occurrence and prevalence of various kinds of defect as well as possible approaches for handling, recovering, and utilizing the defect/character-marked woods.

DESCRIPTION AND EVALUATION OF DEFECTS

Wormy Chestnut—Chestnut with wormhole defect is one of the few character-marked woods that have really "caught on" (fig. 1a). In fact, wormy chestnut is highly prized for use as paneling, picture frames, small furniture pieces, fireplace mantels, and similar decorative items. However, chestnut blight disease was accidently introduced from the Orient in the early 1900's, and by 1940, much of the American chestnut in the Eastern United States had been killed (Clapper and Gravatt 1943). Most of the remaining American chestnut has since succumbed. The chestnut timber worm, *Melittomma servicem* (Harris), immediately attacked the dying chestnut trees, leaving them full of wormholes—hence the name "wormy chestnut." The wormholes range mostly from 1/32 to 3/16 of an inch in diameter. The walls of the holes are usually unstained, and there may or may not be stain in the wood immediately surrounding the holes. The grain in the wood of American chestnut is very attractive, and the wormholes add a great deal of character. Although practically all the chestnut trees have been dead for some time, the wood is very durable and lasting. Scattered dead trees are still standing in the southern Appalachian Mountains; others have fallen but still contain sound marketable wood. While working in the mountains of north Georgia in the early 1960's, I had the opportunity of meeting a couple of local mountaineers. They told me they were locating fallen chestnut logs, dragging them out, and selling them for handsome prices. As recent as 1979, in western North Carolina, I was told that one of the first things that local timber buyers do on new purchases is to survey the tract for dead chestnut trees, standing or fallen—any such discoveries are harvested first. When in western North Carolina in 1980, I attempted to locate a piece of wormy chestnut timber for a fireplace mantel and was shown two stacks of chestnut logs waiting to be sawn at one mill. So even though the supply is limited, small quantities of wormy chestnut are still available.

Spotworm White Oak—Spotworm defect in oaks of the white oak group is well known to woodsmen and lumbermen in some parts of the South, but it also occurs in other areas (fig. 1b). Spotworm defect is caused by a flatheaded borer, *Agrilus acutipennis* Mann. (Morris 1964). The narrow, elongate larvae make long spiraling galleries in the cambium area, packing their borings tightly in the galleries. The wood surrounding each gallery becomes stained. When infested logs are sawn into lumber the defects appear as stained spots shaped somewhat like an oval, diamond, or spindle with irregular or jagged margins at top and bottom. Most spot stains range from 3/4 to 1-1/2 inches in length and slightly less in width. Lar-

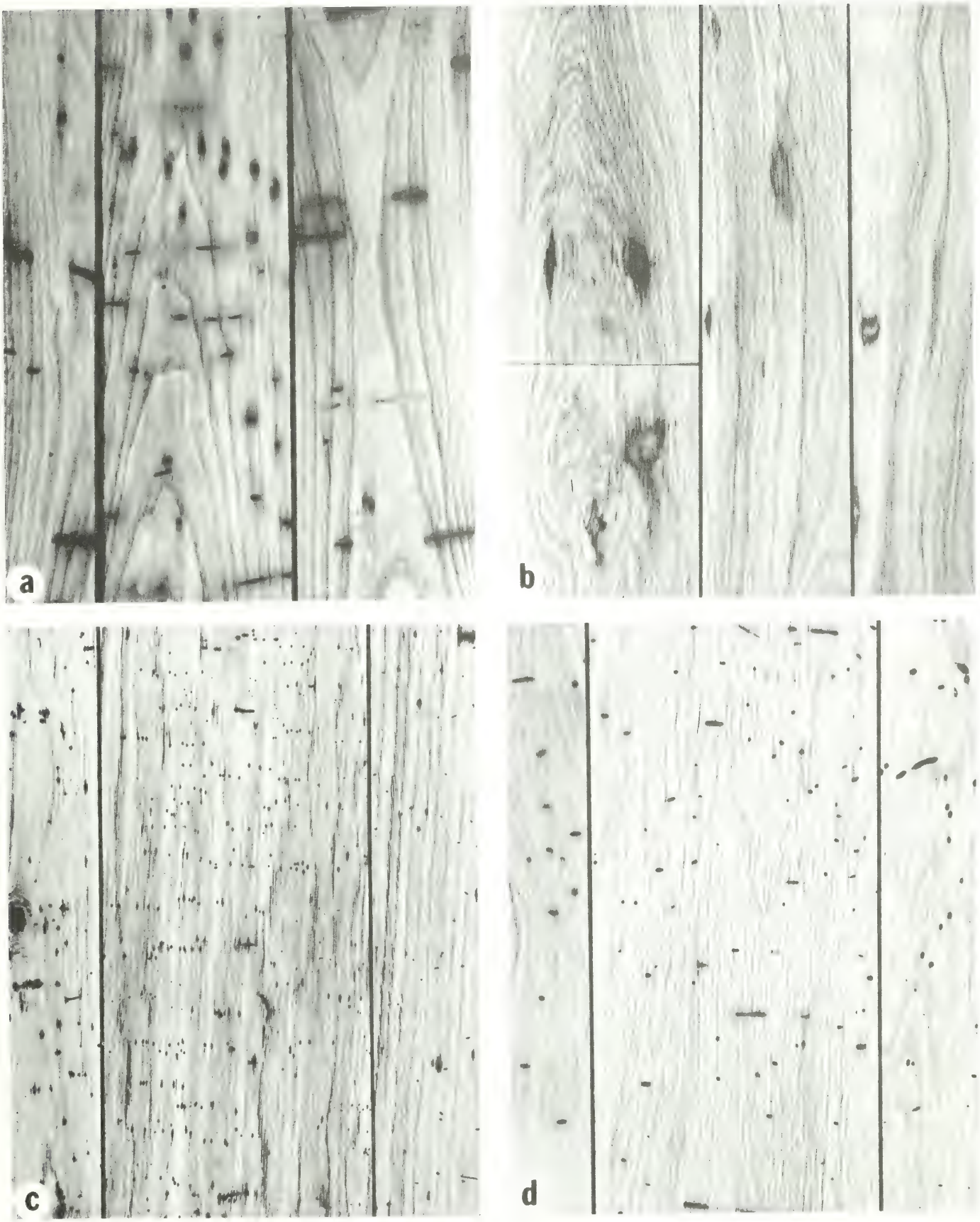

Figure 1.—*Character marks in hardwood lumber: (a) wormy chestnut, (b) spotworm white oak, (c) pinhole oak, (d) timberworm oak.*

val tunnels are only about 1/16 inch in diameter and packed tightly with fine borings that do not fall out during processing. Thus there are no open holes in the finished product. The stain surrounding the frass-packed holes is lighter in color than the normal wood and is bordered by a dark-brown line. The ends of fresh-cut logs usually show irregular lines of stained wood. These lines resemble scribbled handwriting, and woodsmen tend to read them as signs of spotworm and poor wood quality. Lumber with heavy spotworm defect is graded as Sound Wormy or No. 3A Common. Without the defect, much of this lumber would grade No. 1 Common or better—quite a price differential. Lumber selected for spotworm defect makes an attractive and unusual wall paneling without the uniformity of selected clear oak paneling but retaining its warmth and beautiful grain. Timber operators report seeing spotworm oak on bottoms of the lower Ouachita, White, Arkansas, Alabama, and Pearl Rivers as well as many smaller river bottoms in Alabama, Arkansas, Louisiana, Mississippi, and elsewhere.

Pinhole Oak—Pinhole defect in oaks and other hardwoods, caused by ambrosia beetles in the families Platypodidae and Scolytidae, is well known to woodsmen, especially in the warm South (fig. 1c). Although ambrosia beetles are best known for their attacks upon fresh-cut logs and green-sawn lumber as well as dying and recently dead trees, they also attack trees that are stressed and those that are wounded during harvesting and other operations. "Pinhole" is a fairly accurate description of the defect, which is characterized by many small, round holes 1/32 to 1/16 inch in diameter scattered over the surface of the board. The number of holes varies but can be as high as 100 per square foot. The walls of the holes (galleries) are usually dark stained, but the wood surrounding the holes may or may not be stained depending on the condition of the tree when attacked. Trees that are attacked when dying, recently dead, or freshly cut have numerous dark stained holes, but without spot stains in the surrounding wood. Trees that are living when attacked and continue to live for several months or longer usually develop stain in the wood surrounding the galleries. These stains are oval to slightly elongate with irregular margins and commonly measure 1/2 to 2 inches in length. Stains are generally lighter in color than normal wood and resemble the spotworm defect in both appearance and size.

Timberworm Oak—Oak timberworm defect occurs in both red and white oaks (fig. 1d). This defect is caused by the oak timberworm, *Arrhenodes minutus* (Drury). Living and recently dead trees may become infested, but attacks are most commonly associated with wounds, large borer entrances, and other injuries where the bark is removed, thus exposing the sapwood. Larvae tunnel through the wood in all directions, enlarging their galleries as they go. The defects are small, round, unstained holes varying from 1/64 to 3/16 inch in diameter. Oak timberworm defect can be distinguished from pinhole or ambrosia beetle defect by the varying size of the holes and less stain in the holes and surrounding wood. Also, oak timberworm holes are clustered to a greater extent than those made by ambrosia beetles. Oak timberworm defects in the oaks resemble holes made by the chestnut timberworm in wormy chestnut. Thus, oak lumber with timberworm defect has an excellent opportunity of replacing the disappearing wormy chestnut in the marketplace. Oak timberworm defects are quite attractive as character marks; the wood could be marketed separately or perhaps put together with ambrosia beetle pinhole character marks. Oak timberworm defect appears to be most prevalent in the upland areas of the Central States east to Kentucky, Ohio, and West Virginia.

Flagworm Maple—Flagworm defect in maple is well known to many lumbermen (fig. 2a). Flagworm defect, caused by the Columbian timber beetle, *Corthylus columbianus* Hopkins, is responsible for considerable degrade in hardwood lumber and veneer. Hopkins (1894) dated galleries of this insect in West Virginia trees back in 1479, 13 years before the arrival of Columbus. Stains are elongate, tapering to a point at both ends, with one to five dark round holes (gallery channels) slightly over 1/16 inch in diameter, in a line across the stain near the center. Stains are typically 1/4 to 3/4 inch wide at the middle and 3 to 14 inches long. The color of the stain in red maple is usually blue or gray and tan surrounded by a brown border. Wormy lumber from infested soft maple trees is usually put into a special category called WHND (wormholes no defect). This WHND soft maple is sold at about $30/Mbf less for No. 1 Common and Better grades than lumber classified as WHAD (wormholes a defect); WHND soft maple lumber is used mainly for framing of upholstered furniture and in painted and antiqued furniture. Flagworm defects are common in soft maple from southern Illinois and Indiana, southward into the Gulf States and across to Florida. Flagworm in maple is quite different in appearance from other insect defects. The stains form an interesting and appealing macropattern in the wood that adds character to the already beautiful grain. Although the general shape and vertical orientation of the stains tend to be consistent, their different sizes, varying amounts of blue-staining within the "flags," and the occurrence of waviness and curl in the grain of the wood give the stains infinite variation.

Flagworm Sycamore—Flagworm defect in sycamore is also caused by the Columbian timber beetle, *C. columbianus* (fig. 2b). The defect in sycamore is similar to that in the maples except that the stain is light brown instead of blue or gray and is bordered by a more prominent dark-brown line. The flag stains are generally slightly wider and longer, ranging from 3/8 to 1 inch in diameter and 6 to

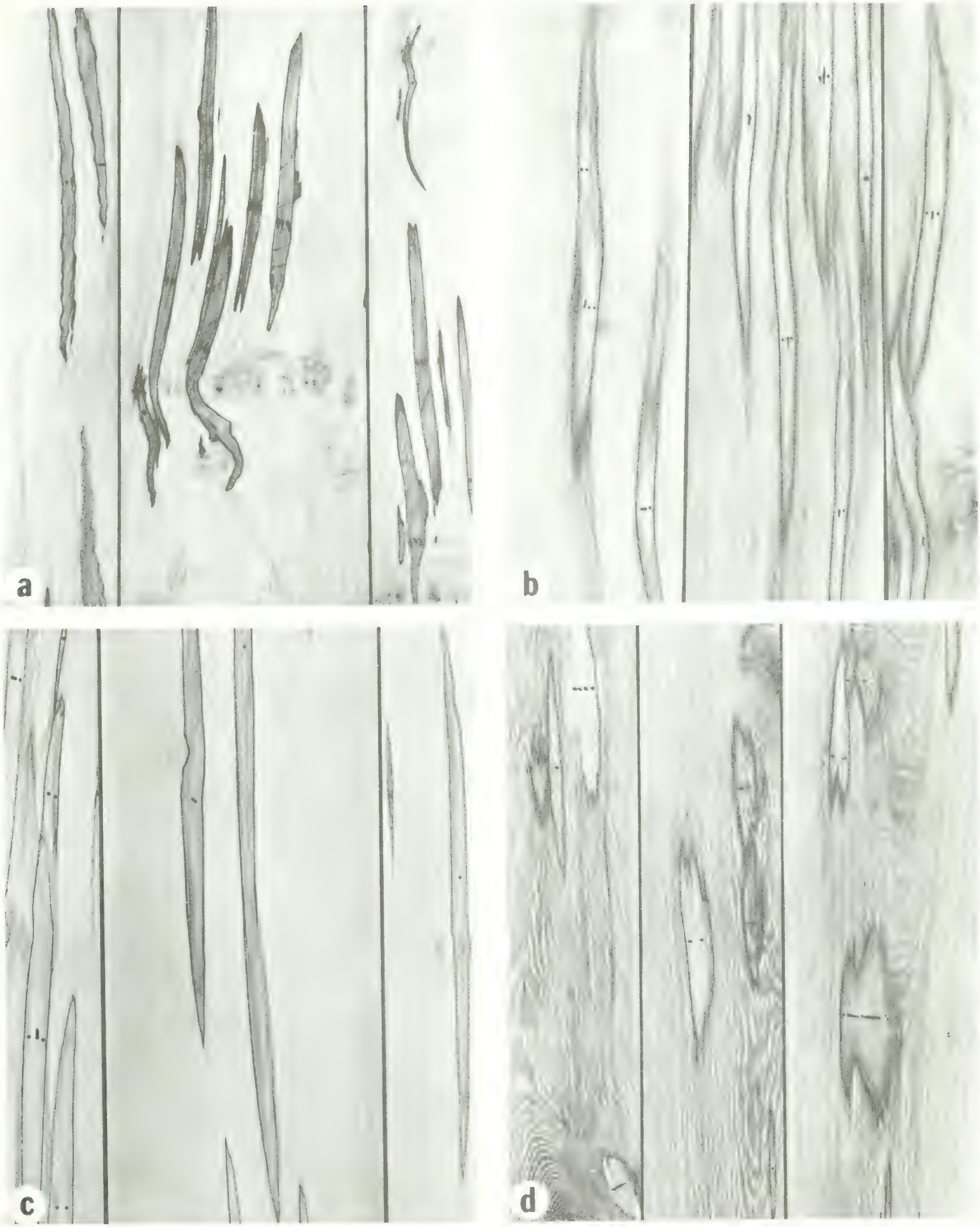

Figure 2.—*Character marks in hardwood lumber: (a) flagworm maple, (b) flagworm sycamore, (c) flagworm boxelder, (d) flagworm white oak.*

18 inches in length. As in maple, the black wormholes and elongate stains enhance the beauty and decorative value of the attractive grain in sycamore wood. Although somewhat less common in sycamore than in soft maple, flagworm defect in sycamore is locally abundant in some bottom land stands. It appears to be more prevalent in stands occupying alluvial sites in major bottoms such as the Mississippi and Tombigbee River drainages. Local stands where nearly every tree exhibits evidence of beetle attack have been observed.

Flagworm Boxelder—Flagworm defect in boxelder is also caused by *C. columbianus* (fig. 2c). The flagworm defect in boxelder is similar to that in maple and sycamore except that the flag stain is light tan with an associated pink or red coloration and is bordered by a brown to gray line. Flag stains in boxelder are about the same diameter as those in maple but are much more variable in length, sometimes ranging up to 24 inches long. The black wormholes centered in the tannish pink-to-red flag stains, with narrow brown borders on the uniformly white wood of boxelder are certainly distinctive and are considered attractive for decorative purposes by many people. Flagworm defect in boxelder is common in local stands, although overall it is less abundant than in soft maple.

Flagworm White Oak—Although flagworm defect in white oak is caused by *C. columbianus,* it is markedly different from the flagworm defects in maple, sycamore, and boxelder (fig. 2d). In white oak the flag stain is much more compact than in other species, wider and shorter, usually ranging from 1/2 to 1-1/2 inches in width and 2 to 5 inches in length. The stain surrounding the black galleries is usually light colored, appearing slightly bleached compared to the normal wood. The lighter colored flag stain is outlined by a dark brown border, giving it a striking appearance. Those who have seen the defect agree that the flag stains and black holes greatly enhance the beauty of the already pleasing grain of white oak. Flagworm is found in local stands of white oak, overcup oak, post oak, and chestnut oak, but it is less common than in maple.

Pith Fleck Maple—Pith fleck defect in maple is well known to lumbermen dealing with both hard and soft maples (fig. 3a). Pith fleck defects are small, narrow, yellowish-to-brown spots or streaks 1/32 to 1/16 inch in width and 1/8 to 2 inches in length that are distinctly darker than the surrounding sap and heartwood. Pith flecks are so-named because of their likeness to true pith; both are composed of parenchyma cells. Pith fleck defect in maple is caused by larvae of the cambium miner, *Phytobia setosa* (Loeb) (Hanson and Benjamin 1967). The larvae hatch from eggs deposited in small branches and mine downward in the cambium in the trunk to the roots. They leave behind tiny burrows that are soon occluded by a cambial growth of dark parenchyma cells and become overgrown in the wood. In face veneers and other high-value products, pith flecks are considered defects and substantially reduce the value. There is little evidence of pith flecks in standing trees, but the defect can be detected on log ends. When pith flecks are numerous or cross the grain, matched and uniform grade face veneers are seriously degraded. *Phytobia* cambium miners are found over much of the United States but are seen most often from the Lake States eastward through New England and southward through the Appalachians.

Gum Spot Cherry—Gum spot defect is all too familiar to forest landowners, timber buyers, and processors dealing with black cherry (fig. 3b). The name "gum spot" concisely describes the defect, which is characterized by a small pocket of gum, dark stain, or bark in the wood. Gum spots may be caused by a variety of factors, but most have been attributed to the feeding of bark beetles, *Pholeotribus liminaris* (Harris) and *Dryocoetes betulae* (Hopk.), and to the cambium miner *Phytobia pruni* (Gross) (Rexrode and Baumgras 1984). The bark beetles feed and overwinter in the living bark of healthy trees causing cambial injuries that result in the formation of gum spots in the wood. Gum spots occur most often in the earlywood and less frequently in latewood. Tree stress brought on by drought or other adverse condition increases the tendency for gummosis when trees are attacked by insects. Veneer grade logs are worth four times as much as factory grade logs, but to meet the veneer grade, logs must be free of gum spots and practically free of other visible defects. Thus, losses to landowners and processors of black cherry can be substantial if gum spot defect is present. Conversely, lumber and veneer containing gum spot defect should be considered acceptable if used as character-marked or decorative woods. Gum spot defects are commonly found in the black cherry producing areas of West Virginia, Pennsylvania, and New York.

Wormy Ash—Wormhole defect in green and white ash is common in many localities throughout the United States and southern Canada (fig. 3c). This defect is characterized by oval to circular wormholes 3/16 to 1/4 inch in diameter. The number of holes in damaged lumber seldom exceeds two or three holes per square foot except in heavily infested timber. The wood immediately surrounding the holes is often stained gray or brown but sometimes the stains are lighter than the normal wood and outlined by dark-brown borders. Stains are somewhat elongate, typically measuring 1/4 to 3/4 inch wide and 1 to 3 inches long. In some cases there are very few stains or none at all. Wormy ash defects are caused by the banded ash borer, *Podosesia aureocincta* Purrington and Nielsen, and the lilac borer, *Podosesia syringae* (Harris). The holes in wormy ash are medium-sized

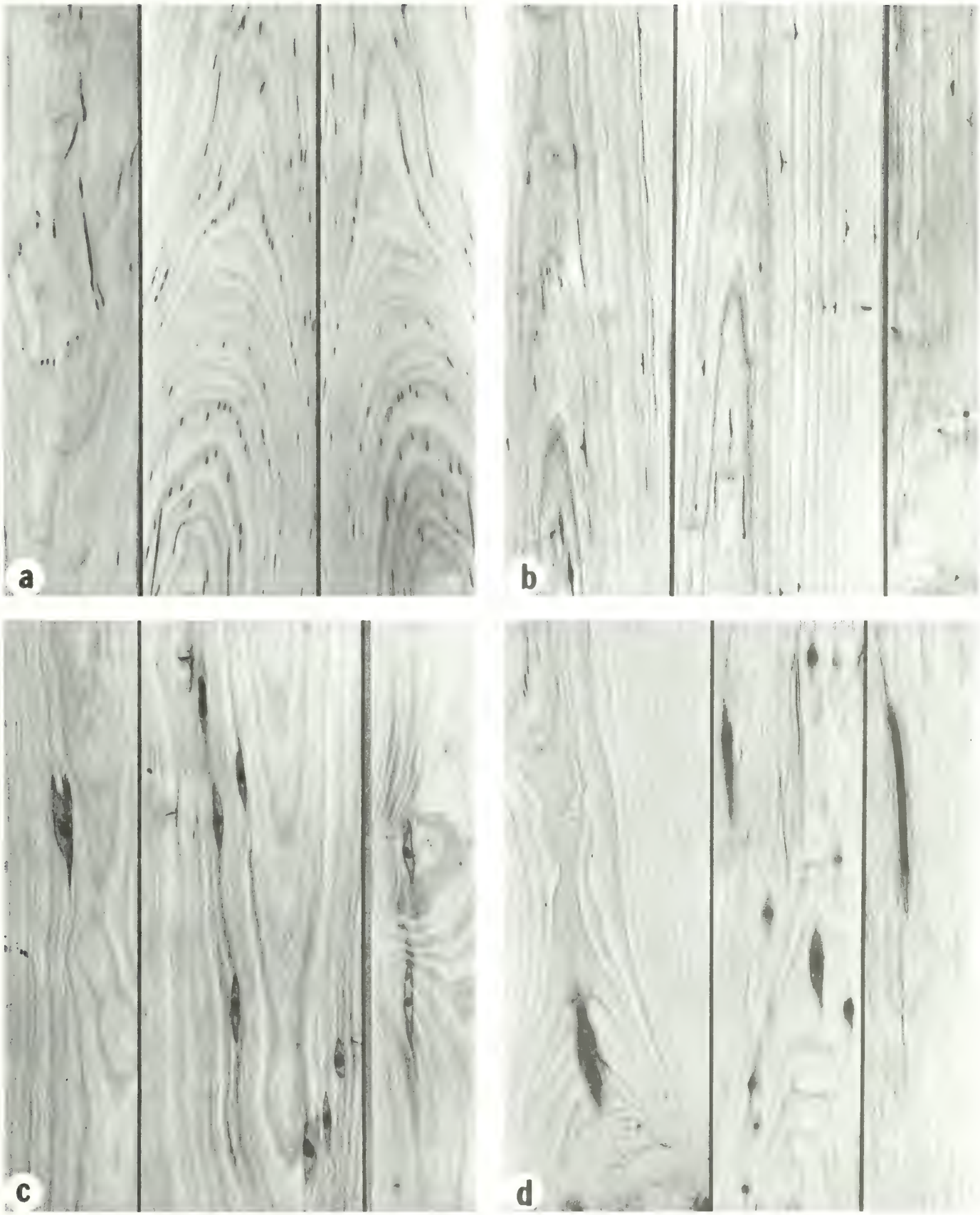

Figure 3.—*Character marks in hardwood lumber: (a) pith fleck maple, (b) gum spot cherry, (c) wormy ash, (d) wormy pecan.*

holes that should be acceptable as character marks to most people.

Wormy Pecan—Wormhole defect in pecan and hickory are seldom abundant over widespread areas, but they commonly occur in some southern localities from South Carolina west to Texas (fig. 3d). The wormhole defects are round to oval holes 1/4 to 3/8 inch in diameter and 2 to 5 inches long. Sawn lumber might include a mix of cross-sectional and longitudinal wormholes. Walls of the galleries are usually stained brown to black. The wood surrounding the holes may or may not be stained; typically it has dark-brown stains measuring 3/8 to 5/8 inch wide and 1 to 4 inches long. Wormholes in pecan may be clustered, although typically the number of holes does not exceed one hole per square foot. Wormy pecan is caused by the pecan carpenterworm, *Cossula magnifica* (Strecker), with its distribution limited to the Southern States and the hickory borer, *Goes pulcher* (Haldeman), distributed throughout the Eastern United States (Solomon and Payne, in press). These medium size wormholes, only slightly larger than those in wormy ash, should be suitable for decorative purposes.

Large Wormhole Oak—Large borer hole defect is prevalent in the oaks and, to a lesser extent, in other hardwood species throughout the United States (fig. 4a). It is characterized by large holes 1/2 to 3/4 inch in diameter and 4 to 8 inches long. Holes may or may not be accompanied by stain or decay. When stains occur they are light to dark brown and elongate, varying from 4 to 10 inches in length. These defects are made mostly by carpenterworms, *Prionoxystus robiniae* (Peck) and *P. macmurtrei* (Guerin), and the red oak borer, *Enaphalodes rufulus* (Hald.). Carpenterworm galleries can usually be distinguished from those of the red oak borer because they are shorter and more rounded in cross-section and have dark stains on the gallery walls. Red oak borer galleries are usually a longer, flattened oval in cross-section and have little or no stain on the gallery walls. Defects caused by these insect borers are considered by many people to be too large for character-marked or decorative grades. Such large wormhole defects, unless filled or backed in some pleasing way, will probably continue to be regarded as defects.

Bark Pocket Oak—Bark pocket defect is a common defect in the oaks, although it may be found in other species as well (fig. 4b). The bark pocket defect is simply an ingrown pocket of bark that can be caused by a variety of agents; in the oaks, this defect is caused mostly by insect borers in the families Cerambycidae and Cossidae. The size and nature of the bark pocket depends on the area of cambium destroyed, tree species, and tree vigor. Most pockets resulting from insect borers are oval to slightly elongate and range from 1/8 to 3/4 inch wide and 1/2 to 4 inches long. Newly hatched borers frequently succumb to heavy sap-ooze while tunneling in the cambium area. When mortality occurs at this point, there are no sapwood tunnels or other evidence of the borer. After the healing process, only an ingrown pocket of bark is left in the wood. Bark pocket defects that are small, hard, and tight and have no associated cavities should fit nicely into a rustic grade, either alone or in a mix with other types of defects. However, large bark pocket defects—those with loose ingrown bark and those with cavities—probably would not be acceptable.

Pecky Cypress—Peck in baldcypress is a defect well known to lumbermen and sawmillers in the Gulf States (fig. 4c). Although baldcypress is not a hardwood, it is often found on low, wet hardwood sites, and its pecky defect resembles borer defects; therefore pecky cypress is included here. Pecky cypress is caused by a fungus, *Stereum taxodii* Lentz and McKay, and is described as a brown pocket rot of the heartwood causing "peckiness" (Toole 1968). The fungus usually gains entrance in the crown and slowly works downward toward the base of the tree. The defect is characterized by long narrow pockets of missing wood where the fungus has softened the wood within the pocket and reduced it to a powder that falls away when the wood is processed, thus leaving open pockets. Pecky defects vary in size but generally range from 1/4 to 1/2 inch in diameter and 2 to 10 inches long. There is also variation in the prevalence of pockets or defects in the lumber. This variation with a degree of uniformity gives pecky cypress a pleasing appearance for paneling, board-and-bat siding, picture frames, and other decorative items. Pecky defect has been described as most prevalent in the upper trunks of old baldcypress. Pecky cypress is readily accepted as a decorative wood, and the demand is growing. In light of this growing demand for wood with such large defects, perhaps there is also some hope for the acceptance of large borer hole defects as character marks.

Pecky Pecan—Bird peck defect is found in a number of woods but is particularly common in pecan and hickory in the South and maple and birch in the North (fig. 4d). Bird peck defect is caused by sapsuckers, primarily by the yellow-bellied sapsucker, *Sphyrapicus varius* (L.) (Dale and Krefting 1966). These birds peck neat rows of closely spaced 1/4-inch holes through the bark and occasionally 1/8-inch deep into the wood. Generally the holes are clustered in rings, or partial rings, around the trunk, although they can be found as a series of vertical holes. When the wounds heal, the resulting defects consist of distortions of the grain, formation of knotty or gnarly growths, and associated elongate stains. These stains are usually moderate to dark brown, but may be lighter around the individual peck marks. Stains in pecan are usually 1/4 to 3/4 inch wide and 1 to 6 inches long. If selected to give variety as well as some uni-

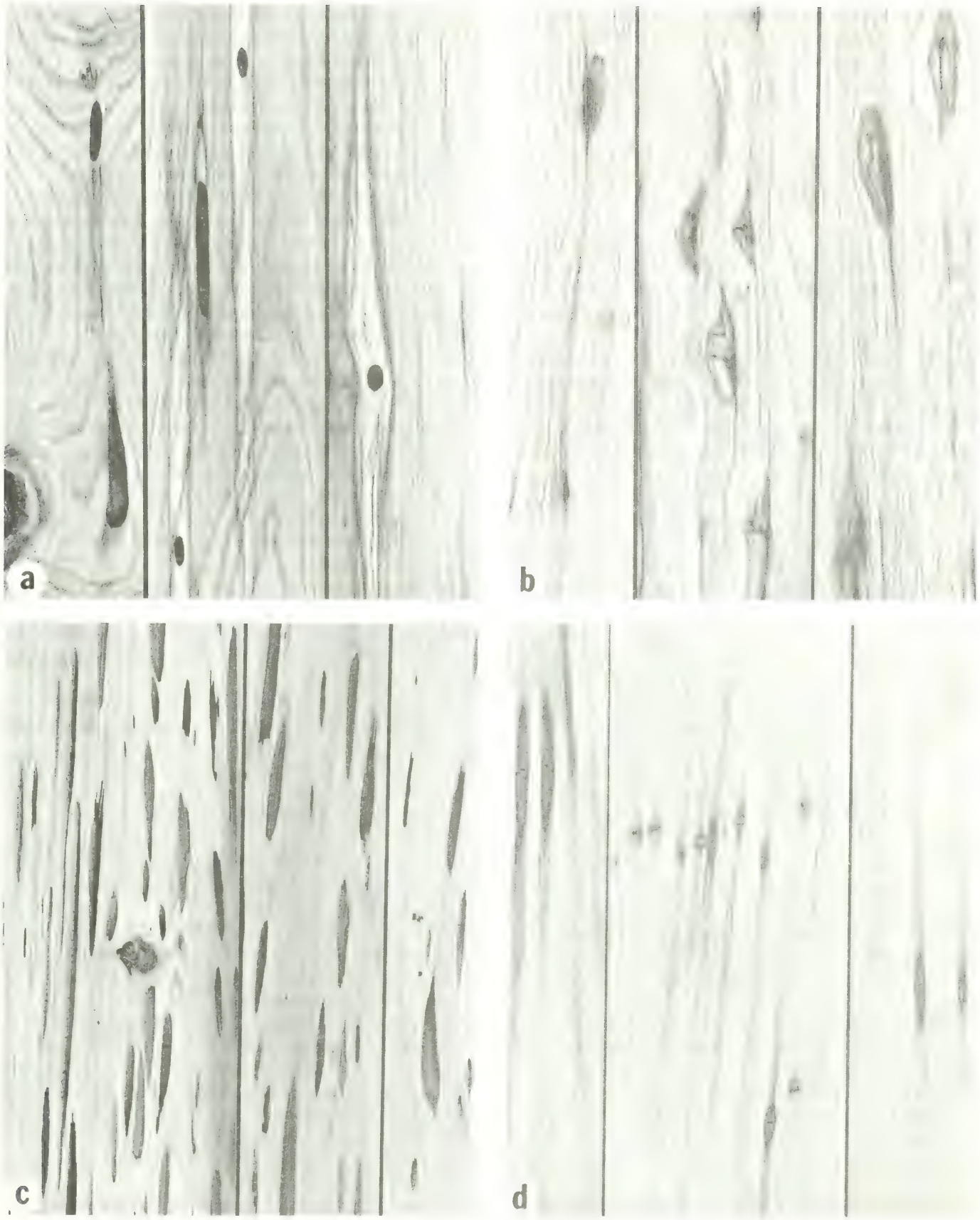

Figure 4.—*Character marks in hardwood lumber: (a) large wormhole oak, (b) bark pocket oak, (c) pecky cypress, (d) pecky pecan.*

formity, bird peck defect should work nicely for paneling, picture frames, some furniture, and other decorative uses. Instead of representing a loss of millions of dollars annually to the lumber industry, bird peck defect could conceivably become sought after as a decorative wood.

CONCLUSIONS

It has been estimated that 9 out of 10 hardwood trees harvested today contain some defect such as borer holes, fungus and chemical stain, bark pockets, and bird peck (Southern Lumberman 1979b). This defective wood need not be downgraded and wasted. Much of it could be used to manufacture unique, beautiful products distinguished by nature's own character marks. Wormy chestnut and pecky cypress have been readily accepted and are already in demand. At least a dozen other kinds of insect-, fungus-, and bird-caused defects have decorative value and should be promoted as character marks. Flagworm defects in maple, sycamore, boxelder, and oak are very attractive, as are spotworm, pinhole, and timberworm defects in the oaks. Pith fleck and streak defects in maple, birch, black cherry, and ash should be considered acceptable. Wormhole defect of medium size, such as those of the *Podosesia* borers in ash and pecan carpenterworm and hickory borer in pecan and hickory, should be acceptable if the wood is selected and presented in a pleasing manner. The large wormhole defect will probably present problems and may remain largely unacceptable; however, the holes are no larger than those in pecky cypress, which people readily accept. Bird defect in pecan and hickory in the South and in maple and birch in the North can be very attractive.

Several of the defects mentioned here might stand alone and be marketed as a specific kind of character-marked wood. In some cases, two or more kinds of defects could be combined, particularly when they occur within a tree species or among closely related species, such as the oak, ash, and pecan-hickory groups.

After logs are sawn into lumber at the mill, there is a fair amount of handling, separating, sorting, and grading for further manufacture or for sale and shipment. Personnel at this level of processing could be trained to recognize and sort or lay aside character-marked lumber. Accumulated character-marked lumber could then be reworked and manufactured into character-marked stock. In certain instances it may prove feasible for some mills to process and manufacture character-marked products at the individual sites. In other instances it may be more feasible to accumulate the character-marked stock and then channel it to one or more centrally located factories specially designed and equipped to manufacture character-marked products such as furniture, paneling, cabinets, picture frames, and mantels.

The following question has been raised: "Is there enough of particular kinds of defect wood to sustain the supply if markets were developed?" Several of the defects, including some of the flagworm defects, pith fleck, spotworm, bark pocket, medium and large wormholes, and bird peck, are prevalent in some regions. Many woodsmen and lumbermen know from past experience that timber harvested from particular locations has a history of specific kinds of defect and always make allowances in buying and selling timber on these sites. Conceivably, entire stands on river bottom lands or other sites known for a particular kind of defect, such as flagworm, pith fleck, spotworm, or bird peck, might be bought, harvested, and milled specifically for the character-marked product. Most of the defects mentioned here can be detected and identified by bark indicators either on the standing tree or log and by "writings" (galleries, mines, stains, and flecks) on the log ends. Butt logs generally contain the highest concentration of borer defects. Timber buyers, loggers, and mill personnel could be trained to recognize sites, standing timber, logs, and lumber with character marked values. By combining kinds of defect, and in some cases even combining pest-caused defect with certain kinds of growth defect, supplies could surely be sustained. The burdensome abundance of low-grade lumber should tell us something about the prevalence of a wide range of defects and thus the possibilities for marketing character-marked woods.

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Sixteen kinds of insect-, fungus-, and bird-caused defects in hardwood lumber that could be used to manufacture character-marked products of exceptional beauty are described and illustrated.

Additional keywords: Low-grade hardwoods, degrade, losses, insect borers, wormholes, stains, sapsucker.

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Optional Forest Yield Taxes in the United States

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and William C. Siegel

SUMMARY

High ad valorem property taxes often discourage forest management. The yield tax is generally considered a less onerous alternative. To encourage good forestry practices, 9 states have enacted 11 optional yield tax statutes. These laws differ substantially in terms of eligibility restrictions, application requirements, and land taxation procedures. To date, only four of the programs—in Massachusetts, Michigan, Missouri and Wisconsin—have attracted substantial numbers of participants. The principal reasons for the generally low landowner acceptance seem to be: (1) absence of an obvious tax advantage, (2) severe eligibility restrictions, (3) unawareness of all relevant tax options, (4) reluctance to relinquish control over certain management decisions, and (5) unwillingness to allow free public access to enrolled acreage.

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INTRODUCTION

The traditional "ad valorem" property tax, which imposes an annual tax on the fair market value of both land and timber, has long been criticized as a method of taxing forest properties. Five major weaknesses have been alleged (Duerr 1960, Gregory 1972) to affect both woodland owners and taxing authorities:

(1) The tax is not equitable—it does not treat equals, in terms of ability-to-pay, equally.

(2) The tax is not neutral regarding the allocation of resources—it encourages reduced stocking levels, shorter rotations, and the movement of marginal forest lands into other uses.

(3) The tax is not convenient in the time and manner of its levy—it mandates annual collections even though most forest properties do not provide annual income.

(4) The tax is not certain as to amount—it can change greatly over the potentially long period of time required to grow timber to maturity.

(5) The tax is not economical—when properly applied it can be costly to administer because forest values are a function of many variables.

To avoid these problems, some of which have been called into question or rendered invalid (Trestrail 1969, Pasour and Holley 1976), many states have enacted special forest property tax laws. One such system, currently employed in 16 states, is the "yield tax" (FICTVT 1984). Under a yield tax, which may be either mandatory or optional, forest land is taxed annually but timber goes untaxed until harvested. A gross income tax, generally equal to some percentage of stumpage value, is then imposed.

Primary advantages of a yield tax, compared to the ad valorem property tax, are: (1) It is easier and less expensive to administer because it eliminates the need to periodically reassess changing timber values; (2) it defers timber taxes until time of harvest, thereby minimizing cash flow problems and enabling forest owners to practice better management; and (3) it allocates the risk of loss due to fire, insects, disease, and price fluctuations between the landowner and the state (Gaffney 1978, Klemperer 1975, Teeguarden 1976). The primary disadvantages cited for the yield tax are: (1) It tends to make governmental revenues less predictable because timber taxes become a function of current stumpage prices and cutting levels; (2) it is biased against the use of better sites, faster growing species, and management practices that result in shorter rotations; and (3) it enables government to build a large equity in growing timber which can badly distort landowner investment incentives in the latter stages of a rotation (Gaffney 1978, Klemperer 1980, Teeguarden 1976).

OBJECTIVES

The last comprehensive survey of U.S. yield tax laws was conducted by Marquis in 1952 (Marquis 1952). The basic purpose of this study was to update that portion of Marquis' work dealing with optional statutes. Specific objectives were to:

(1) Determine which states have optional yield taxes and why they were enacted.

(2) Describe the key provisions associated with each law.

(3) Document administrative responsibilities as well as the nature of any problems being experienced in connection with each program.

(4) Determine the extent to which each statute is being used.

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METHODS

Those states having optional yield tax programs were identified with the aid of several reference sources.[1] Officials in these states were asked to provide copies of all relevant legislation, administrative regulations, and other background material. This information described the key provisions of each law and offered some insights into reasons for enactment. Further information was gained by asking the State Foresters to designate a "resident expert" on their yield tax programs. These individuals were contacted by telephone and asked to respond to a preselected set of questions pertaining to legislative objectives, administrative responsibilities and problems, and enrollment levels and trends.

RESULTS

At present, nine states have 11 optional yield tax laws (table 1).[2] The number of laws exceeds the number of states because Idaho and Michigan have two statutes each. Connecticut's legislation, enacted in 1913, is the oldest. Idaho's 1983 law is the newest. All of the statutes, with the exception of Alabama's, have been amended at least once since 1970.

Reasons for Enactment

The legislation and interview responses indicated that optional yield taxes have been adopted for a variety of reasons (table 2). Encouraging better timber management was a major consideration in all states. Other important motives were to: provide tax relief for forest owners (five states); preserve forest land (four states); encourage reforestation of cutover and/or burned areas (three states); and promote economic and/or industrial stability (three states). Less frequently mentioned objectives included the desire to: stimulate natural resource conservation (two states); encourage multiple use (two states); reduce tax administrative costs (one state); and promote greater tax equity (one state).

Reasons for enacting optional yield taxes do not appear to have changed much over time. Some patterns exist, but their importance is unclear. For example, none of the statutes enacted since 1946 was passed to "provide tax relief to forest owners" or "encourage reforestation of cutover and/or burned areas". Similarly, Idaho's 1983 law was the first to list "reducing tax administrative costs" and "promoting greater tax equity" as objectives. While the significance of these observations is difficult to judge, both probably reflect permanent motivational shifts. In today's political climate, policymakers often consider tax equity more important than tax relief. Also, while reforestation problems still exist, controlling governmental costs takes priority.

Key Legislative Provisions

The key legislative provisions of each optional yield tax are summarized in table 3.

Restrictions on Eligibility.—All states except Alabama limit admissions to their yield tax program. The most common limitation, employed in eight states, is a minimum required acreage. Specified minimums vary from one acre under Michigan's 1917 act to 50 acres in New York. Other common constraints involve minimally acceptable stocking levels or requiring all lands to be devoted to continuous production and harvest of timber. Of lesser importance, because fewer states employ them, are restrictions based on maximum permissible tract sizes, minimum acceptable site productivity potentials, and maximum permissible market valuations for land and/or timber. Two statutes with unique eligibility criteria are Hawaii's "Tree Farm Law" and Idaho's "Reforestation Law". The former restricts enrollment to areas where forestry is the highest and best use. The latter admits only properties needing reforestation.

Application Requirements.—The most common application procedure is to require a contractual agreement. This approach is employed in Alabama, Hawaii, Wisconsin, and Idaho's "Reforestation Law". Contracts vary from 5 to 50 years, and normally mandate perpetuation of the present land use and management of all timber according to accepted forestry practices. Other lesser used procedures require submission of either initial, periodic, or annual applications. Initial applications are used in Connecticut, with Idaho's 1983 law, and Michigan's 1925 statute. Periodic applications are used in Massachusetts and Missouri; annual applications apply only to Michigan's 1917 legislation. New York has the most unusual process. There participants must commit their land to timber production for 10 years, recertify this

[1]These reference sources were:

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[2]Not included in this total are three optional yield taxes applicable only to properties already enrolled. These are Louisiana's 1910 Reforestation Contract Severance Tax, Minnesota's 1927 Auxiliary Forest Tax, and New York's 1926 Fisher Forest Tax Law. Washington's Reforestation Act of 1931 has also been excluded because it was phased out of existence in 1984.

Table 1.—*Existing optional yield tax laws, 1984*

State	Title	Legal citation	Year enacted	Year last amended
Alabama	Auxiliary Forest Law	Code of Alabama, Title 9, Chap. 13, Secs. 40-50.	1923	1945
Connecticut	General Statutes Title 12, Chapter 203	Connecticut Gen. Stat. Ann., Title 12, Chap. 203, Secs. 96-103.	1913	1973
Hawaii	Tree Farm Law	Hawaii Revised Stat., Title 12, Chap. 186, Secs. 1-12.	1963	1983
Idaho (1)	Reforestation Law	Idaho Code, Title 38, Chap. 2, Secs. 201-223.	1929	1974
Idaho (2)	Taxation of Forest Lands & Forest Products	Idaho Code, Title 63, Chap. 17, Secs. 1701-1708.	1983	1984
Massachusetts	Chapter 61, Forest Land Assessment Law	Massachusetts Gen. Laws Ann., Title 9, Chap. 61, Secs. 1-8.	1914	1981
Michigan (1)	Commercial Forest Act	Michigan Stat. Ann., Title 13, Chap. 98, Secs. 201-211.	1925	1980
Michigan (2)	Private Forest Reserve Act	Michigan Stat. Ann., Title 13, Chap. 98, Secs. 221-228.	1917	1977
Missouri	State Forestry Law	Ann. Missouri Stat., Title 16, Chap. 254, Secs. 010-300.	1946	1981
New York	Section 480a, Taxation of Forest Land	New York Real Property Tax Laws, Sec. 480a.	1974	1979
Wisconsin	Forest Crop Law	Wisconsin Stat. Ann., Title 10, Chap. 77, Secs. 01-16.	1927	1975

Table 2.—*Reasons cited for enactment of existing optional yield tax laws*

	Statute and year enacted										
Reasons for enactment	AL 23	CT 13	HI 63	ID (1) 29	ID (2) 83	MA 14	MI (1) 25	MI (2) 17	MO 46	NY 74	WI 27
Encourage better timber management	X	X	X	X	X	X	X	X	X	X	X
Provide tax relief for forest owners	X			X		X			X		X
Preserve forest land		X		X			X			X	
Encourage reforestation	X			X			X	X			
Promote economic stability									X	X	X
Encourage natural resource cons.		X						X			
Encourage multiple use									X		X
Reduce tax administrative costs					X						
Promote tax equity					X						

Table 3.—*Key provisions of existing optional yield tax laws, 1984*

State and title of law	Restrictions on eligibility	Application requirements	Tax treatment of timber	Tax treatment of land	Withdrawal penalties and other features
Alabama					
"Auxiliary Forest Law"	None. Applicable to any tract of land devoted to reforestation or forest culture generally.	Must enter into a 5-year contractual agreement with the state. Under its terms, the property must be adequately protected and cannot be used for any purpose that will inhibit the growth of the timber thereon.	All timber is taxed at 8 percent of its estimated value at the time of cutting.	Tracts of 160 acres or less are exempt from the ad valorem tax. Tracts of over 160 acres are taxed on the basis of their value as bare forest land at the time of enrollment.	Properties must remain in the program for at least 5 years. Landowners who elect to withdraw after that time must pay a "privilege tax" equal to 8 percent of the appraised value of all standing timber.
Connecticut					
"General Statutes Title 12, Section 203"	Tracts must be 25 or more acres in size and cannot have a bare land value in excess of $100 per acre. They must bear tree growth in such quantity and so spaced as to constitute a forest area in the opinion of the State Forester.	Must file initial application only. The application must include a description of the land and a sworn statement from the assessor which gives the value of the land and timber separately.	On tracts bearing timber more than 10 years old, a graduated scale is employed. Timber cut within 10 years of enrollment is taxed at 2 percent of its estimated value. This rate increases in 1 percent increments for every 10 years until age 50. All timber cut after 50 years from the date of enrollment is taxed at 7 percent of its estimated value. On tracts bearing timber less than 10 years old, the tax is 10 percent of the estimated value of all products cut. Material cut for domestic use by the forest owner or a tenant is exempt from taxation.	Land and timber are valued jointly at the time of classification and this valuation remains fixed for 50 years. Each year the local tax rate, up to a maximum of 10 mills, is applied to the pre-set value to determine the amount of tax due.	Properties withdrawn from the program are subject to a penalty tax based on the amount by which land and timber values increased during the period of enrollment. The actual tax due is determined by multiplying the value increase by a tax rate of 10 mills per annum and aggregating over all the years that the property was enrolled. Properties sold within 10 years of classification are subject to a "conveyance tax". This tax varies, by 1 percent increments, from 1 to 10 percent of total sales price. The highest rate applies to tracts sold during the first year of enrollment, the lowest to those sold during the tenth.
Hawaii					
"Tree Farm Law"	Tracts must be 30 or more acres in size and capable of producing trees of commercial species in sufficient quantity to establish a business in the sale thereof. Forestry must be the highest and best use of the land.	Must enter into a 30 year contractual agreement with the state. Under the terms of this agreement, the landowner must manage the property in accordance with regulations established by the Board of Land and Natural Resources.	On tracts bearing timber less than 10 years old, the tax is 10 percent of the estimated value of all products cut. On all other tracts, the tax is 5 percent of the estimated stumpage value. Material cut for domestic use by the forest owner is exempt from taxation.	Exempt from the real property tax.	Properties withdrawn from the program are subject to a penalty charge consisting of two components. First, all land taxes saved during the period of enrollment are recouped with a 5 percent interest charge. Secondly, a tax equal to 5 percent of the estimated value of all standing timber is imposed. All participants are required to submit a formal management plan.

Table 3.—*Key provisions of existing optional yield tax laws, 1984—Continued*

State and title of law	Restrictions on eligibility	Application requirements	Tax treatment of timber	Tax treatment of land	Withdrawal penalties and other features
Idaho (1)					
"Reforestation Law"	Tracts must be in need of reforestation and must be suited—by virtue of their location, topography, and geological formation—to the growing of trees. Tracts that were timbered prior to enrollment must have been harvested in accordance with regulations established by the State Board of Land Commissioners.	Must enter a 50 year contractual agreement. Under its terms, the landowner must manage the property in accordance with regulations established by the State Board of Land Commissioners. Payment of a $1 application fee is required.	All timber is taxed at 12.5 percent of its estimated value at the time of cutting. Material cut for domestic use by the forest owner, or for use in harvesting the forest crop, is exempt from taxation.	Taxed at local rates on a fixed assessment of $5 per acre.	Properties withdrawn from the program are subject to a penalty charge equal to the difference between the taxes that were actually paid and those that would have been paid without enrollment. All participants are required to submit a formal management plan. Public access for hunting, fishing, and camping must be allowed.
Idaho (2)					
"Taxation of Forest Lands & Forest Products"	Tracts must be from 5 to 2,000 acres in size and devoted to the continuous production and harvesting of timber.	Must file initial application only. Upon approval, the yield tax option must be elected over the productivity tax option. This election is binding for a period of 10 years.	All timber is taxed at 3 percent of its estimated value at the time of cutting. Material cut for domestic use of the forest owner is exempt from taxation. However, the exemption is not to exceed $25 in any one year.	Taxed at local rates and on the basis of assessments which reflect the current use value of forest land when devoid of timber. Assessments are established by the State Tax Commission and vary with geographical location and site productivity.	Properties withdrawn from the program are subject to a penalty charge. To determine this charge the current local tax rate is multiplied by the current difference between a property's assessed valuations with and without the program and the number of years it was enrolled—up to a limit of 10. This product, net of any yield taxes paid during the period of enrollment, represents the penalty. Some counties require participants to submit a formal management plan.
Massachusetts					
"Chapter 61 Forest Land Assessment Law"	Tracts must be 10 or more acres in size and cannot be used for any purpose that will reduce the quantity or quality of the forest crops produced. The area must be at least 16.7 percent stocked, have 7.5 $ft.^2$ or more of basal area per acre, or be a plantation with 500 or more trees per acre.	Must file a new application every 10 years. Must pay an application fee based on the number of acres to be enrolled. Owners of tracts of from 10 to 100 acres pay $1 per acre subject to a $25 minimum and, of tracts over 100 acres, $.75 per acre subject to a $200 maximum.	All timber is taxed at 8 percent of its estimated value at the time of cutting.	Taxed at local rates and on the basis of an assessment equal to 5 percent of the land's estimated fair cash value. The assessment cannot be less than $10 per acre.	Properties withdrawn from the program are subject to a penalty charge. This charge is computed by aggregating—for the preceding 5 years or the period of time since last recertification, whichever is longer—the difference between the taxes actually paid and those that would have been paid without the program. Interest charges

Table 3.—*Key provisions of existing optional yield tax laws, 1984—Continued*

State and title of law	Restrictions on eligibility	Application requirements	Tax treatment of timber	Tax treatment of land	Withdrawal penalties and other features
					are added to the deferred tax payments. All participants are required to submit a formal management plan.
		Landowners who cut timber within 2 years prior to making application are required to pay a tax equal to 8 percent of the estimated value of the products removed.			
Michigan (1)					
"Commercial Forest Act"	Tracts must be 40 or more acres in size and cannot contain any material natural resources other than forest growth. They must be devoted to the continuous production and harvesting of timber and may not be used for agricultural, mineral extraction, grazing, industrial, developed recreational or resort purposes. The land must be capable of producing a thrifty forest growth and, at the time of enrollment, must carry sufficient stocking to give assurance that a stand of merchantable timber will be produced within a reasonable period of time.	Must file initial application only.	All timber is taxed at 10 percent of its estimated value at the time of cutting. Material cut for domestic use by the forest owner, or for use in harvesting the forest crop, is exempt from taxation.	Taxed at the rate of $.30 per acre per year.	Properties withdrawn from program are subject to a penalty charge which depends on the number of years that they were enrolled. For properties enrolled for less than 20 years, the penalty consists of two parts. The first part is determined by multiplying the current average ad valorem tax on cutover forest land in the township by the number of years, not to exceed 7, that the property was enrolled. The second part is determined by taking 10 percent of the estimated stumpage value of all merchantable timber products on the land. For properties enrolled for 20 or more years, the penalty consists of just the 10 percent of stumpage value fee. Public access for hunting and fishing purposes must be allowed. The State pays the counties $.70 per year for each acre of land in the county classified under the program. The counties, in turn, pay $.25 per acre per year to the townships where the enrolled lands are actually located.
Michigan (2)					
"Private Forest Reserve Act"	Forested areas must be between 1 and 40 acres in size and part	Must file annual applications.	All timber is taxed at 5 percent of its estimated value immediately after cutting, but before removal.	Taxed at local rates on the basis of an assessment which cannot exceed $1 per acre.	Properties withdrawn from the program are

Table 3.—*Key provisions of existing optional yield tax laws, 1984—Continued*

State and title of law	Restrictions on eligibility	Application requirements	Tax treatment of timber	Tax treatment of land	Withdrawal penalties and other features
	of a tract not in excess of 160 acres. At least half of the property must be improved and devoted to agriculture. The forested area, if newly established, must contain at least 1,200 well distributed trees per acre. The comparable stocking requirements for stands which exceed 10 or 25 years of age are 500 or 250 trees per acre, respectively.		Material cut for domestic use by the forest owner or a tenant is exempt from taxation.		subject to a penalty charge equal to 5 percent of the estimated stumpage value of all standing timber. Grazing is not permitted in newly established stands until 90 percent of the trees are two or more inches in diameter.
Missouri					
"State Forestry Law"	Tracts of 20 or more acres that are devoted to timber growing and for which the market value of land and timber combined does not exceed $400 per acre.	Must file a new application every 25 years.	All timber is taxed at 6 percent of its estimated value at the time of cutting. Material cut for domestic use by the forest owner is exempt from taxation.	Taxed at local rates and on the basis of a fixed assessment of either $1 or $3 per acre. The lower assessment applies to properties enrolled prior to 1974 and the higher to those enrolled thereafter.	Properties withdrawn from the program are subject to a penalty charge. The amount of the charge depends on who initiates the withdrawal action—the landowner or the State. In the case of properties declassified by the landowner, all in-lieu of tax payments made by the Conservation Commission must be repaid along with 5 percent interest thereon. In the case of properties declassified by the State, the penalty is the same except that interest is computed at a rate of 10 percent. All participants are required to submit a formal management plan. The State Conservation Commission pays the counties $.50 per year for each acre of land in the county enrolled under the program.
New York					
"Section 480a, Taxation of Forest Land"	Tracts of 50 or more acres which are devoted exclusively to timber production and which are stocked with a stand of trees sufficient to	Must covenant to retain the land in timber production for at least 10 years. This commitment must be recertified annually.	All timber removed in commercial cuttings is taxed at 6 percent of its estimated value at the time of cutting.	Taxed at local rates but on the basis of a reduced assessment defined to be the greater of the following: (1) 20 per-	Properties withdrawn from the program are subject to a penalty charge. The penalty is the greater of the following: (1) 2 times the taxes that would have

Table 3.—*Key provisions of existing optional yield tax laws, 1984—Continued*

State and title of law	Restrictions on eligibility	Application requirements	Tax treatment of timber	Tax treatment of land	Withdrawal penalties and other features
	produce a merchantable forest crop within 30 years of initial certification.	Payment of a $25 application fee is required.	Material cut for domestic use by the forest owner is exempt from taxation as long as the amount does not exceed 5 cords per year.	cent of the assessment that would apply in the absence of the program; or (2) the assessment that would apply in the absence of the program minus the amount by which this assessment exceeds $40 per acre multiplied by the applicable equalization rate.	been paid in the preceding year had the property not been classified; or (2) 2.5 times the taxes that would have been paid on the property's exempted assessment during the period of enrollment, not to exceed 10 years, plus 6 percent interest compounded annually. All participants are required to submit and adhere to a formal management plan.
Wisconsin[1]					
"Forest Crop Law"	Tracts of 40 or more ares which are better suited to producing timber and other forest crops than they are to any other purpose. Minimum required stocking levels depend on stand size. Seeding size stands must contain at least 200 trees per acre, sapling size stands at least 100 trees per acre, pole timber size stands at least 3 cords per acre, and sawtimber size stands at least 1,300 board feet per acre.	Must enter a contractual agreement stipulating that the land will be devoted to the practice of forestry. Contracts, at the landowner's option, can vary from 25 to 50 years in length.	All timber is taxed at 10 percent of its estimated value at the time of cutting. Material cut by the forest owner for use as fuel is exempt from taxation.	Classified lands are subject to an annual tax known as an "acreage share". For properties enrolled on or before December 31, 1971, the acreage share is $.10 per acre. For properties enrolled since that date, the acreage share is $.74 per acre. This rate will be adjusted in 1992 and every 10 years thereafter.	Properties withdrawn from the program are subject to a penalty charge. The nature of the penalty depends on when a property is withdrawn. Tracts declassified prior to the expiration of the applicable contractual agreement are subject to a penalty which equals the difference between the taxes that would have been paid without the program and those that actually were paid, both in the form of acreage share and yield tax payments. The difference is computed for the entire period of enrollment and is to include a 5 percent interest charge (12 percent for contracts signed after March 15, 1978) on all deferred taxes. Tracts declassified at the expiration of the applicable contractual agreement are subject to a penalty equalling 10 percent of the estimated stumpage value of all standing timber which they contain. All participants are required to submit a formal management plan.

Table 3.—*Key provisions of existing optional yield tax laws, 1984—Continued*

State and title of law	Restrictions on eligibility	Application requirements	Tax treatment of timber	Tax treatment of land	Withdrawal penalties and other features
					Public access for recreational, hunting and fishing purposes must be allowed. The Department of Natural Resources pays individual towns $.20 per year for each acre of land in the town enrolled under the program.

[1]In July of 1985 the Wisconsin legislature enacted a new optional yield tax called the "Managed Forest Act". This new law, which will become effective in January of 1987, replaces the "Forest Crop Law" except for those contracts already in effect.

commitment annually, and pay a $25 application fee. The only other states that levy an application fee are Idaho (under its "Reforestation Law") and Massachusetts.

Tax Treatment of Timber.—Most existing laws defer all tax obligations until harvest. The two exceptions are Connecticut's law and Michigan's 1917 statute. In Connecticut, land and timber are valued jointly when a property is enrolled, and the amount of tax due each year is then determined by multiplying this preset value by the applicable local tax rate, not to exceed 10 mills.[3] When timber is cut, a second tax is imposed. The rate of this tax varies, depending on the age of the stand and the years of enrollment. For stumpage sales, the rate is applied to the price received. If the owner cuts his own timber, the stumpage value is estimated, subject to review by the town government. Under the Michigan act, no timber tax is levied until harvest, but cut timber cannot be removed until the tax is paid. The local assessor determines the taxable value of the severed timber.

Taxable timber values under the other optional yield tax laws are variously determined, depending upon the state. In some instances, actual stumpage prices received are used. In others, stumpage values—which may or may not equal the actual prices received—are set by the taxing or other public authority for each particular harvest. In still other states, pre-determined regional or statewide stumpage values for various species and products are used.

Tax rates are also highly variable. At one extreme, in Connecticut, timber more than 10 years old which is cut from tracts enrolled for 10 years or less is taxed at only 2 percent of value. At the opposite extreme, timber cut from tracts classified under Idaho's "Reforestation Law" is taxed at 12.5 percent.

[3]Initial assessments are fixed for a period of 50 years; after this time they are subject to adjustment.

Most optional yield tax laws stipulate that certain timber products can be cut without being taxed. The most frequent exemption, employed under eight laws, applies to trees cut by landowners and/or their tenants for domestic use. Other exemptions, provided in three statutes, apply to timber used in harvesting operations or removed during noncommercial cuttings.

Tax Treatment of Land.—Some type of annual tax on land is specified in all of the existing legislation except Hawaii's "Tree Farm Law" and Alabama's "Auxiliary Forest Law". The former exempts all enrolled properties from any land tax. The latter exempts only participating parcels of 160 acres or less in size.

Procedures for determining land taxes vary widely. Generally, local tax rates are applied to a modified assessment. Four laws—Alabama's, Connecticut's, Idaho's 1929 statute, and Missouri's—use a fixed assessment; three laws—Massachusetts', Michigan's 1917 statute, and New York's—use a reduced assessment; and one law—Idaho's 1983 legislation—substitutes "use" for "market" valuation.

The two remaining statutes—Michigan's "Commercial Forest Act" and Wisconsin's "Forest Crop Law"—employ a fixed tax as opposed to a modified assessment. In Michigan, the tax is presently $.30 per acre per year. In Wisconsin, the amount depends on the enrollment date. For tracts classified on or before December 31, 1971, it is $.10 per acre per year. For tracts classified since 1971, it is $.74 per acre per year. The latter figure will be subject to adjustment in 1992 and every 10 years thereafter.

Withdrawal Penalties and Other Features.—All existing optional yield tax laws contain provisions designed to promote achievement of specific goals. Two of the more important goals are to: (1) minimize the impacts of tax deferment and modified assessment on local governmental revenues, and (2) ensure that society gains some benefit from the favorable tax treatment being extended to forest owners.

To minimize adverse impacts on local governmental revenues, all the statutes levy a penalty for program withdrawal. The penalties differ widely, but two procedures predominate. Under the first approach, employed in four laws, the penalty is based on the estimated stumpage value of all merchantable timber on a tract at the time of declassification. Under the second approach, also used in four laws, the penalty is based upon the difference between the taxes that were actually paid during the period of enrollment and those that would have been paid except for the program. In addition to these withdrawal penalties, three statutes—Michigan's 1925 law, and those of Missouri and Wisconsin—authorize state in lieu of property tax payments to those counties and/or towns that contain participating properties. At present the payments are $.70 per acre per year in Michigan, $.50 per acre per year in Missouri, and $.20 per acre per year in Wisconsin.

To ensure public benefits, six of the existing programs—Hawaii's, Idaho's 1929 law, Massachusetts', Missouri's, New York's, and Wisconsin's—require formal management plans. Idaho's 1929 law, Michigan's 1925 legislation, and Wisconsin's statute also mandate public access to enrolled properties for hunting, fishing and recreational purposes.

Administrative Responsibilities and Problems

Responsibilities.—The existing optional yield tax statutes employ three approaches to program administration (table 4). The first entails centralization of all administrative duties at the state level. This procedure is employed under five of the laws—Michigan's 1925 statute, and those of Alabama, Hawaii, Missouri, and Wisconsin. The second approach involves centralization of some duties at the state level and delegation of others to individual counties and towns. The state duties normally include ascertaining eligibility and monitoring compliance with stipulated land management requirements. Local officials usually collect any taxes due. This type of arrangement is specified by five laws—Connecticut's, both of Idaho's, Massachusetts', and New York's. The third administrative approach, used only under Michigan's 1917 law, delegates all administrative duties to the local level.

Primary responsibility for the administration of most programs rests with the State Department of Natural Resources or a comparable agency. Somewhat surprisingly, State Revenue Departments tend to play a relatively minor role, except in Alabama and Hawaii, and with Idaho's 1983 statute.

Problems.—Inability to collect consistently all yield tax revenues and withdrawal penalties is the most pervasive problem being encountered by tax administrators (table 5). This difficulty was cited in connection with 5 statutes—Connecticut's, Idaho's 1929 law, Michigan's two laws, and New York's. The next most prevalent problem—mentioned in connection with Idaho's 1983 law, Michigan's 1917 statute, and Wisconsin's legislation—is the inability to realize fully the desired public benefits. The primary benefits

Table 4.—*Administration of optional yield taxes, 1984*

Statute	Program administration	Tax collection
Alabama	Forestry Commission & Department of Revenue	Forestry Commision
Connecticut	State Forester	Town tax collectors
Hawaii	Board of Land and Natural Resources	Department of Taxation
Idaho (1)	Board of Land Commissioners	County Treasurers
Idaho (2)	Tax Commission	County Treasurers
Massachusetts	Division of Forests and Parks	Town tax collectors
Michigan (1)	Department of Natural Resources	Department of Natural Resources
Michigan (2)	Town & County Conservation Commissions	Town tax collectors
Missouri	Conservation Commission	Conservation Commission
New York	Department of Environmental Conservation	County Clerks
Wisconsin	Department of Natural Resources	Department of Natural Resources

Table 5.—*Administrative and enforcement problems, 1984*

Problem	Statute										
	AL	CT	HI	ID (1)	ID (2)	MA	MI (1)	MI (2)	MO	NY	WI
Yield tax revenues and withdrawal penalties not consistently collected		X		X			X	X		X	
Intended public benefits not always realized					X			X			X
Records inconsistent and poorly kept				X							X
Local governments experiencing revenue shortfalls							X			X	
Taxes shifted onto nonforest owners										X	

alluded to are better timber management and improved public access for hunting and fishing. Poor record keeping was identified as a concern in only two instances—with respect to Wisconsin's statute and Idaho's 1929 law.

In a somewhat different vein, revenue shortfalls and tax shifting present problems in Michigan and New York. Shortfalls make it difficult to provide public services and could lead to pressures for program repeal. Tax shifting from forest to nonforest owners might also increase the pressure for change. Indeed, this response is almost certain to occur if the programs are not seen as providing any significant public benefits.

Various explanations were offered for the preceding problems, three of which were particularly important. First, deficiencies in some of the enabling legislation have been a source of difficulty, especially failure to require a management plan, failure to require public access, and reluctance to exclude properties that are too small to form economic management units. Secondly, hostility of local tax officials has sometimes hindered program implementation. Finally, inadequate staffing has occasionally been a source of trouble.

The causes of the tax revenue and tax shifting problems were not addressed by the study respondents, but have been discussed in various studies of use assessment (Coughlin et al. 1978, Keene et al. 1976). These analyses indicate that unless steps are deliberately taken to counter the two difficulties, one or both of them will inevitably occur as a consequence of granting preferential tax treatment to selected taxpayers.[4] They also indicate that the magnitudes of the two problems tend to be inversely related and are determined essentially by the interplay of three factors (Coughlin et al. 1978, Keene et al. 1976):

(1) The amount of tax relief granted to the favored taxpayers. Other things being equal, both problems will become more serious as the amount of relief increases.

(2) The proportion of the total value of the tax base held by the favored taxpayers. Other things being equal, both problems will become more serious as this proportion increases.[5]

(3) The degree to which tax rates can be freely adjusted. Other things being equal, flexible rates will accentuate tax shifting whereas inflexible rates will accentuate revenue shortfalls.

Enrollment Levels and Trends

In his 1952 study, Marquis found little use of optional yield taxes. Less than 3 percent of all privately owned commercial forest land within the 12 states that had statutes at that time was enrolled (Marquis 1952). The situation appears much the same today.

Current Enrollment Levels.—Participation was measured on both a landowner and an acreage basis (table 6). The number of landowners enrolled ranged from none in Hawaii to 3,200 in Wisconsin. In no state, however, did registrants exceed 6.5 percent of all eligible forest owners. Participation levels on an acreage basis were slightly higher. Enrolled acreage ranged from none in Hawaii to just over 2 million acres under Michigan's 1925 law. On a percentage basis, Wisconsin, with 26 percent, was the only state where more than 10 percent of the eligible acreage had been enrolled under the yield tax program.

Enrollment Trends.—No enrollment trend data were available for Idaho's 1983 and Michigan's 1917 statutes. Idaho's law was too new. Enrollment records for Michigan's legislation are kept by individual towns and thus would have been difficult to obtain.

Programs that have experienced stable enrollments during the past 5 years are Alabama's, Connecticut's, Hawaii's, and Idaho's 1929 statute. Programs that

[4]The in lieu of tax payments made under Michigan's "Commercial Forest Act", Missouri's "State Forestry Law", and Wisconsin's "Forest Crop Law" are representative of the type of corrective action that might be taken.

[5]In actuality, the relationship between the tax-shifting problem and the proportion of the tax base which receives favorable tax treatment is not always a direct one. Beyond some point, as the proportion of the tax base receiving favorable tax treatment increases, total tax-shifting begins to decline. In the extreme case where all taxable property receives favorable treatment, there would be absolutely no tax-shift.

Table 6.—*Enrollment in existing optional yield tax programs, 1984*[1]

Statute	Estimated forest owners eligible for enrollment[2]	Actual owners enrolled	Estimated owner participation	Estimated area of forest land eligible for enrollment[2]	Actual area enrolled	Estimated acreage participation
	------- *Number* ------		*Percent*	*MM acres*	*Acres*	*Percent*
Alabama	202,000	1	.0005	20.3	2,000	.01
Connecticut	20,000	179	.9000	1.4	29,773	2.17
Hawaii	30	0	0.0000	1.0	0	0.00
Idaho (1)	41,000	50	.1200	3.0	130,000	4.33
Idaho (2)	25,000	**	**	3.0	**	**
Massachusetts	41,100	2,000	4.8700	2.2	146,800	6.56
Michigan (1)	**	500	**	**	2,003,000	**
Michigan (2)	**	**	**	**	800	**
Missouri	**	1,010	**	8.0	310,112	3.88
New York	100,000	285	.2800	5.5	102,752	1.87
Wisconsin	50,000	3,200	6.4000	5.0	1,300,000	26.00

[1] ** indicates no data available or the value cannot be computed.

[2] Estimates were obtained from the "resident experts" as identified by the State Foresters in each state. (See *Methods* section.)

have experienced enrollment gains, both in terms of landowners and acreage, are Massachusetts', New York's, Wisconsin's, and Michigan's 1925 law. Annual participation increases have ranged from 5 percent in Michigan to 10 percent in Wisconsin. The only state to experience declining enrollment is Missouri. There both the number of landowners and acreage have been dropping at a rate of 4 to 5 percent annually.

Causes of Low Enrollment.—Marquis attributed the low level of usage which he observed in 1952 to six factors: (1) lack of knowledge, (2) administrative restraints and red-tape, (3) forest practice restrictions on enrolled acreage, (4) lack of sympathy or opposition by public officials, (5) stringent eligibility requirements, and (6) absence of a clear tax advantage (Marquis 1952). Many of these same obstacles continue today (table 7).

Most frequently cited by the 1984 respondents as a reason for current low levels of participation was the lack of an obvious tax advantage. Other explanations, in order of decreasing importance, were: (1) severe eligibility restrictions, (2) the programs are not well known, (3) government control over management decisions, and (4) public access requirements. Eligibility restrictions perceived to be troublesome differed among states. For Idaho's 1929 law and Massachusetts' law, the specified commitment period was considered to be too long. For Connecticut's statute, the maximum permissible land and timber value was believed to be too low. Finally, for Michigan's 1925 law, the minimum acreage requirement was felt to be too high.

The "other" response category in table 7 reflects factors that are unique in particular states. In Hawaii, "too much red-tape" was cited as a problem. For Idaho's 1983 law, poor administration by local tax officials was listed as a difficulty. Finally, in New York, stringent declassification penalties are apparently discouraging participation.

CONCLUSIONS AND RECOMMENDATIONS

While participation is necessary for the success of any public program, it is no guarantee of success. Of the data compiled here, however, enrollment figures provide essentially the only objective basis for evaluating program performance.

Judged solely on the basis of use, it can be concluded that most of the existing optional yield taxes are failures.[6] The only moderately successful statutes are Massachusetts' "Forest Land Assessment Law" (2,000 owners and 146,800 acres), Michigan's "Commercial Forest Act" (500 owners and 2,003,000 acres), Missouri's "State Forestry Law" (1,010 owners and 310,112 acres), and Wisconsin's "Forest Crop Law" (3,200 owners and 1,300,000 acres). These exceptions indicate that optional yield taxes can be effective if properly designed.

Examination of the successful laws and discussions with the "resident experts" led to the following suggestions for improving the acceptability and performance of optional yield taxes:

- An optional yield tax should be implemented only in those states in which forest landowners need some

[6] Some have argued that an optional yield tax, even when unutilized, can have a positive effect on the forest tax situation by encouraging restraint in the application of the ad valorem tax to forested properties.

Table 7.—*Major reasons for landowners not participating in optional yield tax programs, 1984.*[1]

Reason for low enrollment	Statute										
	AL	CT	HI	ID (1)	ID (2)	MA	MI (1)	MI (2)	MO	NY	WI
Little or no tax advantage	X		X		X				X	X	X
Eligibility requirements too stringent		X		X		X	X				
Programs' existence not well known							X	X	X		X
Government given some control over management decisions			X						X		X
Must allow public access				X			X				X
Other			X		X					X	

[1]Obtained from the "resident experts" as identified by the State Foresters in each state. (See *Methods* section.)

form of tax relief to manage forests profitably. Furthermore, it should be adopted over other alternatives only if it can be shown to be the most efficient, equitable, and politically acceptable method of providing relief.

• An optional yield tax should be administered, except for tax collection, by the agency most knowledgeable about forestry—generally the state's forestry agency. Collection should be performed by those most capable of handling it, normally the local tax collectors.

• Yield and annual property tax obligations should be structured so that the average forest owner does not receive an "excess" subsidy. Ideally, after adjustments for differences in risk, participants should earn their alternative rate of return and no more. Additional earnings result in a greater incentive than necessary to induce enrollment.

• Some type of state-level revenue sharing arrangement should be instituted to ensure that local taxing jurisdictions do not suffer severe revenue shortfalls because of the yield tax program. Since optional yield taxes are supposed to provide important "pubic benefits", it is only fair that their costs be borne by all taxpayers.

• Landowners should be required to pay an application fee to enroll in an optional yield tax program. This fee should allow the administrative costs of classifying a property to be at least partially paid by the landowner.

• An optional yield tax law should clearly define eligible forest land in order to accomplish the objectives of the law. For example, if the legislative purpose is to increase timber production in the state, only commercial forest land should be eligible for enrollment. A vague definition can lead to inequities and inefficiencies.

• Landowners should be required to have a management plan and to periodically update it. This will ensure that enrolled properties are managed in keeping with the program's objectives.

• When a property is removed from an optional yield tax program, other than by means of eminent domain, the landowner should be assessed a penalty. It should equal the taxes saved because of the program, plus an appropriate interest charge. Such a provision would help ensure that enrollees do not use the program as a "tax dodge" or for land speculation.

• Once an optional yield tax has been enacted, it should be widely publicized to inform prospective participants.

Adherence to these guidelines will not necessarily guarantee the acceptability of an optional yield tax program. The evidence suggests, however, that utilization will maximize the chances of success.

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High ad valorem property taxes often discourage forest management. The yield tax is generally considered a less onerous alternative. But the yield tax is not without problems, which, along with solutions, are explored in this report.

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The Woody Biomass Resource of Alabama

James F. Rosson, Jr. and Charles E. Thomas

CONTENTS

INTRODUCTION 1
METHODS AND DISCUSSION 2
STATE CHARACTERISTICS 3
RESULTS 5
OWNERSHIP 9
FOREST TYPE 10
HARVESTING 11
LITERATURE CITED 12
APPENDIX 13
  RELIABILITY OF THE DATA 13
  DEFINITIONS 13
  SPECIES LIST 15
  TABLES 18

The Woody Biomass Resource of Alabama

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INTRODUCTION

The extent of total live biomass in a forest ecosystem is summarized by the following classical equation (Odum 1971):

$$\text{Biomass Accumulation} = \text{Gross Productivity} - \text{Plant Respiration} - \text{Animal Respiration} - \text{Saprobe Respiration}$$

This biological equation ignores the human influence on the accumulation of woody biomass. When forests are disturbed by cutting, another reduction factor is introduced to the right side of the equation. Consequently, this has a drastic affect on the overall accumulation of biomass in the forest community.

All of society's wood products originate from woody plants photosynthetic process of organic matter. In the distant past, this forest production was viewed from a lumberman's perspective. Today, the forests of North America are perceived differently than they were only 20 years ago. New viewpoints and forest values now recognize more than lumber use. Recreation, watershed protection, and the wildlife ecosystem are seen also as products of the forest. Beyond this is a new perception of the forest as a large standing stock of utilizable vegetative biomass (phytomass). Many business concerns have become very interested in utilizing this forest biomass as a fuel to supplement or replace petroleum as its supply diminishes and/or its prices rise.

If forest biomass becomes a substantial component of fuel supply, certain resource supply/demand issues become evident. This, in effect, will impact on the future of forest biomass as a renewable resource element. To supply a growing demand for biomass fuel, certain limited management options are available to managers: (1) establishing fuel forests, by planting fast growing species such as pine, sycamore, sweetgum, and cottonwood (planted and cut on very short rotations of 10 years or less); (2) utilizing the non-merchantable upper portion of merchantable trees that are harvested for lumber or paper and utilization of non-merchantable trees; (3) reducing pulpwood consumption by recycling paper and using the diverted wood fiber for fuel; (4) competing with paper and lumber industries for existing forest stands (and thus possibly resulting in option 3).

All of the above approaches, except the third, could have an adverse effect on long-term soil quality maintenance. Jenny (1980) has illustrated that continual removal of one-third or more of the organic residues remaining after tree harvest would have a dramatic effect in reducing soil fertility and water-holding capacity of soils. He also cites several studies demonstrating that continued removal of forest litter and residues, with corresponding organic matter reductions, results in reduced yields and loss of soil texture. Mineral fertilizers can enhance short-term yields but do nothing to restore important soil texture. Concern is growing about maintaining both physical and chemical soil characteristics where total above-ground biomass is removed, especially at frequent intervals (Barber and Van Lear 1984, Bengtson 1981, Kellison 1983, Odum 1983, Phillips and Van Lear 1984).

Potential users of wood energy are the forest industry, light-duty industry, public institutions (schools, hospitals, power companies) and homeowners (primarily heat). In the southern U.S., approximately 50 percent of the forest products industry is energy self-sufficient, with the goal to be totally so in the near future. Approximately 60 percent of the wood energy will come from mill residues, the remainder from forest residues (Kellison 1983). Because oil prices have decreased since 1979, use of wood residues as energy has fallen off.

The organizations that continue to use wood fuel directly from the forest conclude that, presently, this supply must be free stumpage and within a 25-mile radius of the user facility to be economically feasible (Kellison 1983).

Today in the U.S., 3 percent of the total gross energy consumption involves biomass fuels (Department of Energy 1983). By the year 2000, biomass could provide as much as 11 percent of the nation's energy needs (Energy Research Advisory Board 1981). A slight drawback to this is that the energy expended to collect, transport, and convert vegetative biomass to energy results in a net potential energy yield of 5 percent to United States energy production (Energy Research Advisory Board 1981).

It is clear that benefits and risks are associated with all phases of any form of energy production. The

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direct and indirect costs and benefits of utilizing biomass for energy need to be identified and evaluated. The first step in this process involves identification of the resource and its quantity, composition, distribution, and potential availability.

This paper is the second by the Southern Forest Experiment Station Forest Inventory and Analysis Work Unit to characterize the forest biomass resource of a Midsouth State.

METHODS AND DISCUSSION

The fifth Alabama forest inventory was completed in 1982 (Rudis et al. 1984). The primary focus of this project described the growing-stock volume and depicted its distribution throughout the State. In all, 87,000 trees were measured on 3,723 sample plots. The detailed information obtained on these trees is readily adapted to individual allometric, tree biomass equations currently available in the literature.

The Alabama inventory recorded 82 commercial tree species and 19 noncommercial species out of the 127 species listed for the 7 Midsouth states (see Appendix). Also, several infrequent noncommercial species were lumped into a single species category. Prediction equations are not currently available for each of these species.

General equations developed for the softwood, soft hardwood, and hard hardwood groups were used to estimate weights for species in which no coefficients are yet developed. In many instances, species specific coefficients were applied to other species similar in morphology and specific gravity. For example, coefficients have not been developed for all the oaks, thus specific coefficients from other oak species were applied to make these weight estimates. This resulted in a better estimate than with the use of general equations. Recent work has demonstrated that multispecies biomass regressions give an estimate similar to that derived from species- and site-specific tree regressions (Freedman 1984). Even so, refinement of biomass estimates will continue in the future as more individual tree species biomass work is completed.

Appropriate species equations were then applied to the primary tree measurements obtained in the inventory. For trees greater than 5.0 inches in diameter at breast height, tree diameter and total height formulae were used for weight estimates. Trees smaller than 5.0 inches in diameter were estimated using an equation based on diameter alone.

The equations applied were developed for sample trees located on the Gulf and Atlantic Coastal Plain and Piedmont Provinces (Clark et al. 1985 and Clark pers. comm.). Although many of these equations came from areas outside of Alabama, it is believed that the physiographic similarities between the sample plot locations and the area of the Alabama inventory were appropriate for biomass estimates. It is recognized that regional differences in morphological characteristics occur among species but it is not always possible to obtain equations from specific areas inventoried. Analyses of regional species equations have demonstrated intra-species differences. For the most part, these differences occur among hardwoods and have been largest toward the drier portions of the West Gulf. Our approach was to use the most suitable equations available at the time for a given area. Investigators of regional vegetation biomass will have to deal with this problem for some time into the future.

Another problem with our estimates may be in applying these equations to understocked stands or planted stands, common in extensive inventories, because the equations are based on trees growing in natural, fully stocked stands. Estimates for trees with atypical crowns, taper, and weight per cubic foot may be slightly distorted.

In this paper, we present the information in green (fresh) weight. While recognizing that the appropriate and most commonly used scientific approach is to report information in dry weight per square meter, we feel that initial planners, managers, and strategists would prefer green weight, a common and standard purchase unit in the wood using industry. There are no scientific standards established, as yet, for presenting biomass information. The literature is diverse in methodology of component measurement techniques, components reported, and units of measure.

Total biomass, or total green (fresh) weight, is defined as the total weight of wood and bark from a 1-foot stump to the end of the twigs (see Appendix). No dimension limit on the twig end is defined. Fruits, flowers, and leaves are excluded but current year twig growth is included. The merchantable green weight is the weight of wood and bark from a 1-foot stump to a 4-inch top or larger (i.e., some stem anomaly may terminate bole length before a 4-inch top is reached). This includes the log and pole portion of growing-stock trees. The residual is the green weight of the remaining wood and bark of the stand after the merchantable component has been subtracted. This includes the crown weight of merchantable trees plus total sapling weight, total rough and rotten tree weight (minus cull deduction in rotten trees only), and total noncommercial tree weight. Again, fruits, flowers, and leaves are not included in the residual green weight component. Also, stump and roots are not included as a component or in a component anywhere in this report.

The information in this paper is meant to be both informative and useful. Correlating biomass with basal area will allow users to make rough estimates of available biomass for areas they inventory. Basal area per acre is one of the most accurately assessed

variables in the forest survey. It is a consistent and proven measure that can be reliably repeated in the field or adopted to previously inventoried stands. Basal area measurement by other investigators has consistently passed scientific objectivity criteria. When coupled with the number of stems per acre it can be used as a basis for estimating stand growth and yield or other measures of productivity. Research has repeatedly demonstrated the high correlation of basal area with volume and height (Daniel et al. 1979, Husch et al. 1982).

The inclusion of additional statistical information about basal area may help resolve stand structure problems. The basal-area and green-weight per-acre relation can be specified more completely if variances and higher statistical moments are computed. Disturbed stands with a large proportion of the harvestable basal area removed but which maintain a significant component of large trees may show average basal area similar to a young stand which has only numerous small diameter trees. Biomass for the two stands would be vastly different, but the additional statistical moments would allow an estimate of these differences. To our knowledge, no such work has been done at this time.

Many survey plots with low basal area are characterized by a few large trees and numerous small trees. Most likely, plots with low basal area are understocked (a result of disturbance) or are extremely young.

Basal area may be used cautiously as a surrogate for time in stands that do not clearly show an even-aged stand structure. An increase in basal area coupled with a relative contribution of small trees to the total stand basal area can be used to characterize stand development. Total biomass development can then be related to basal area statistics. These estimates may be considerably enhanced by the inclusion of stand average-height and a measure of species morphology.

Citing the above reasons, basal area may provide a more realistic and objective assessment than stand age in the portrayal of biomass estimates, especially for forest survey's mixed-age plots. Even though the literature contains documentation of the correlation between an increase in basal area and an increase in age, most of that work involved natural stands that were well stocked and undisturbed over a long period of time (Odum 1971, Whittaker 1975). This finding does not apply well to heavily disturbed stands where low stocking, in combination with a plurality of larger and older trees, will result in a biomass factor not representative of the age of the stand. Of course, in such instances, stand age determination becomes extremely difficult and highly subjective. It is highly probable that stand age increases as biomass and basal area increase. However, much work needs to be done on disturbed stands before conclusions regarding age and basal area can be drawn.

Correlation of biomass with stand age may also be useful to users but is somewhat limited because of the field limitations in determining ages of particular forest stands. Stand age is one of the most difficult and subjective parameters estimated by inventory field crews. To control consistency checks, Southern Station field crews only assign an exact age to stands that plainly have a plurality of stocking in one age class. In reality, this means that stands with a plurality of trees in a certain diameter and height range are given an age based on ring counts of 3 representative sample trees. Stands disturbed or that regenerated in waves over 10 to 30 years, so that not even one or two age groups are identifiable, are placed in the mixed-age category. The field crews do not have ready access to quantitative information necessary to assign stand age on these questionable, often heavily disturbed stands, where stand classes cannot be recognized consistently among different foresters. With stand age so assigned, we are confident that even-aged plots are in fact even-aged and subsequently stands are not forced into wrong age categories. Age information can be misleading if the wrong plurality is assigned to a plot and, consequently, the wrong trees are bored.

An effort has been made to report available harvest-residual biomass on 18,130,000 acres of timberland in Alabama. This information is compiled only for upland pine sites—i.e., sites on which pine is present or was formerly present. Bottomland sites and hardwood sites (pine totally absent) were not tabulated because harvesting information was not collected on these sites during the inventory. Approximately 3,500,000 acres of mixed hardwood and bottomland sites are excluded from this portion of the analysis.

The biomass of individual cut or removed trees on harvested plots was computed from predicted-diameter-only equations. Trees left standing were measured and the diameter-height equation used. The estimates in various cutting categories give a potential residual green weight, not a utilized residual green weight as it was not possible for field crews to determine whether any residual biomass was utilized on these sites, either through whole tree logging or other systems.

STATE CHARACTERISTICS

To facilitate forest inventory processes, Alabama is divided into 6 survey units: Southwest-South (Unit 1), Southwest-North (Unit 2), Southeast (Unit 3), West Central (Unit 4), North Central (Unit 5), and North (Unit 6). Much of the information presented in this paper is by survey unit (fig. 1). This approach readily portrays regional characteristics of the State.

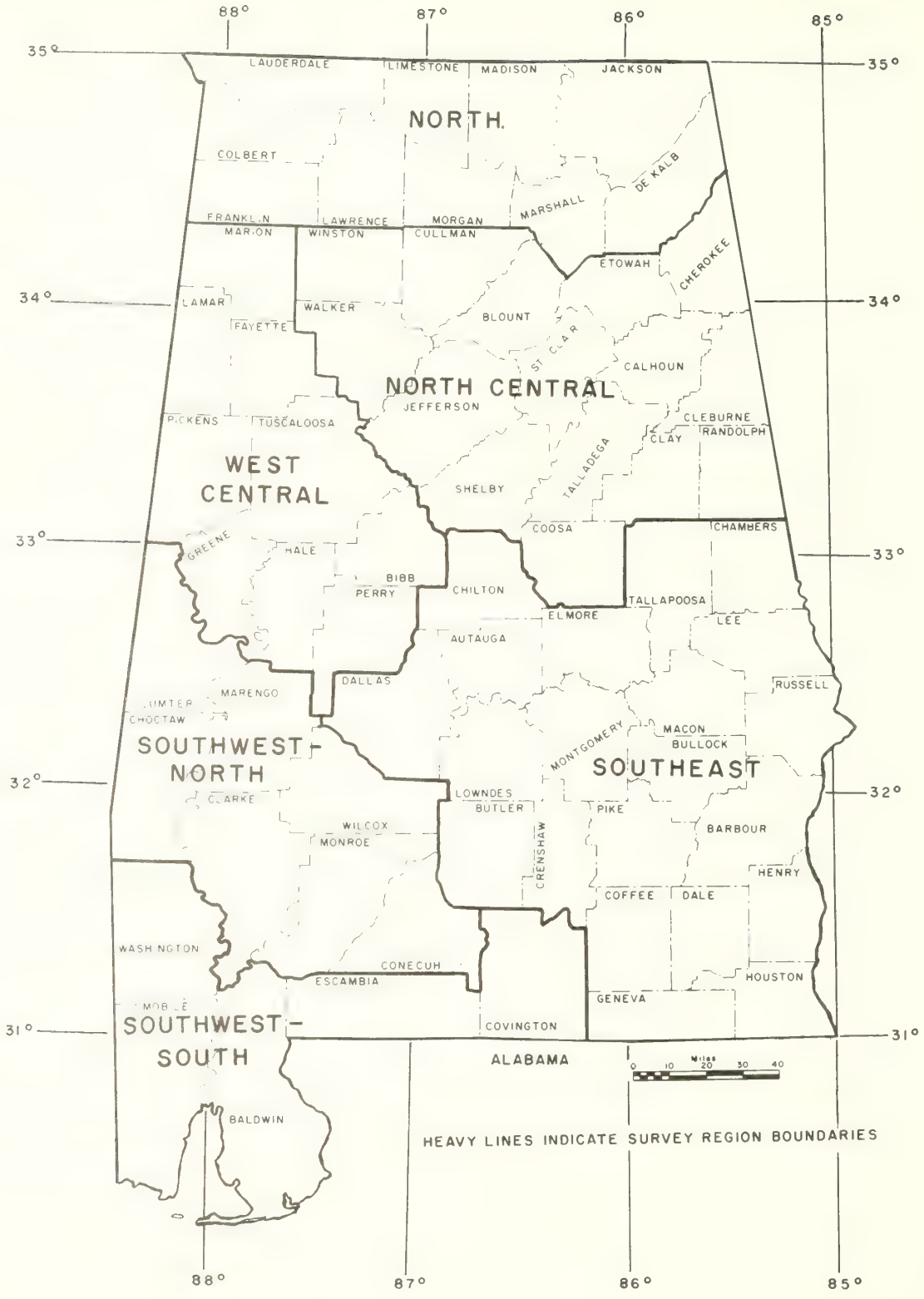

Figure 1.—*Forest survey units in Alabama.*

Since the survey units are aligned with county boundaries, they do not correspond precisely with forest community or geologic boundaries but they do approximate a relatively close correlation with geologic provinces. Most of Alabama lies on the Gulf Coastal Plain below the Fall Line (fig. 2). Included on the Coastal Plain are such major geologic features as the Fall Line Hills, Black Belt, Red Hills, and Southern Pine Hills (Fenneman 1938). The survey units on the Coastal Plain (Southwest-South, Southwest-North, Southeast, and West Central) contain 14,928,600 acres of timberland. The North unit, with 2,187,700 acres of timberland, lies mostly on the Highland Rim Province and the Tennessee Valley proper with the easternmost counties on the Cumberland Plateau. The North Central unit is mostly on the Cumberland Plateau, Coosa Valley, and the Dahlonega Plateau (Piedmont Province). There are 4,542,600 acres of timberland in the North Central unit.

Statewide, timberland totals 21,658,800 acres, 67 percent of the total 32,545,400 acres in the State. With two-thirds of the State in trees, forest vegetation dominates the landscape.

RESULTS

Total green weight of woody biomass in Alabama is 1,551.2 million tons. This is divided into 793.8 million tons of green merchantable weight and 757.5 million tons of green weight residual biomass, almost an even division between these two major components. However, this is an abstract representation and may actually be misleading. Softwood trees morphologically have a larger proportion of their stems in the merchantable section than do hardwoods. Also, softwood trees contain a lesser amount of rough and rotten components (part of the residual) than do the hardwoods. Statewide, 69 percent of the total softwood biomass is in the merchantable component, while only 39 percent of total hardwood biomass is in the merchantable section of hardwoods. When softwoods and hardwoods are combined in Statewide totals, averaging masks the dissimilarities between the two.

Figures 3 and 4 graphically portray the relative distribution of softwood and hardwood biomass throughout the State. In general, hardwood quantities are higher than softwood quantities across the State, but especially so in the southwest, west central, and northeast areas.

Alabama forests average 71.6 tons of green biomass per acre, with 43.2 tons from hardwood and 28.4 tons from softwood. The combined softwood and hardwood merchantable portion averages 36.7 tons per acre and the combined residuals average 35.0 tons per acre. Most of the 28.4 tons per acre of softwood biomass is merchantable, 20.0 tons per acre, leaving 8.4 tons per acre of residual. In contrast, of the 43.2 tons per acre of hardwood, 17.1 tons per acre are merchantable whereas 26.1 tons are residual.

Total biomass concentrations in Alabama, by unit, range from 81 tons per acre (North unit) to 59 tons per acre (Southwest-South unit). The predominance of hardwood in the North unit accounts for most of this higher concentration of biomass. The Southwest-South, Southeast, and North Central units are lowest in biomass density per acre. The forests in these units contain a higher proportion of pine and this contributes to these lower levels.

When comparing the survey units irrespective of density, the Southeast unit has the highest amounts of total green weight, merchantable green weight, and residual green weight. The Southwest-South unit contains the least amounts of total and residual

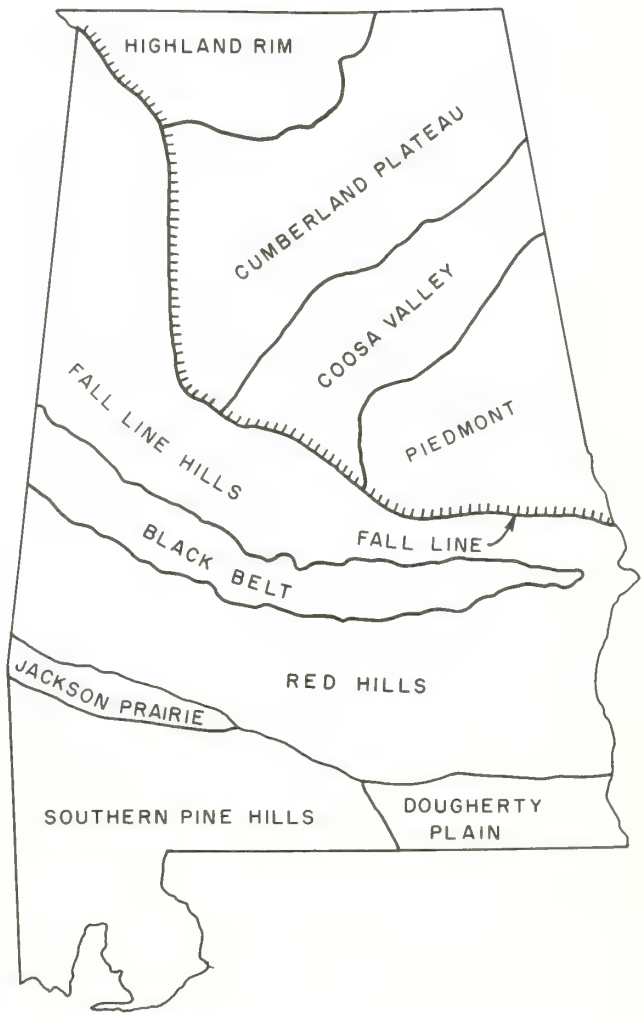

Figure 2.—*Physiographic regions in Alabama.*

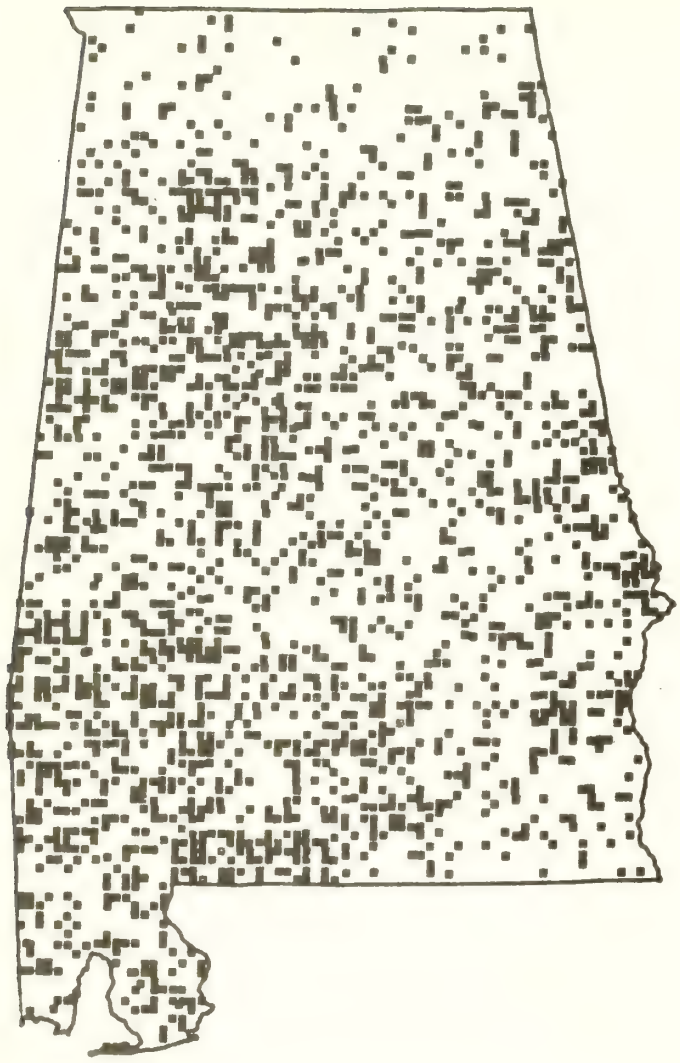

Figure 3.—*Distribution of softwood biomass, each dot representing 300,000 tons woody green weight.*

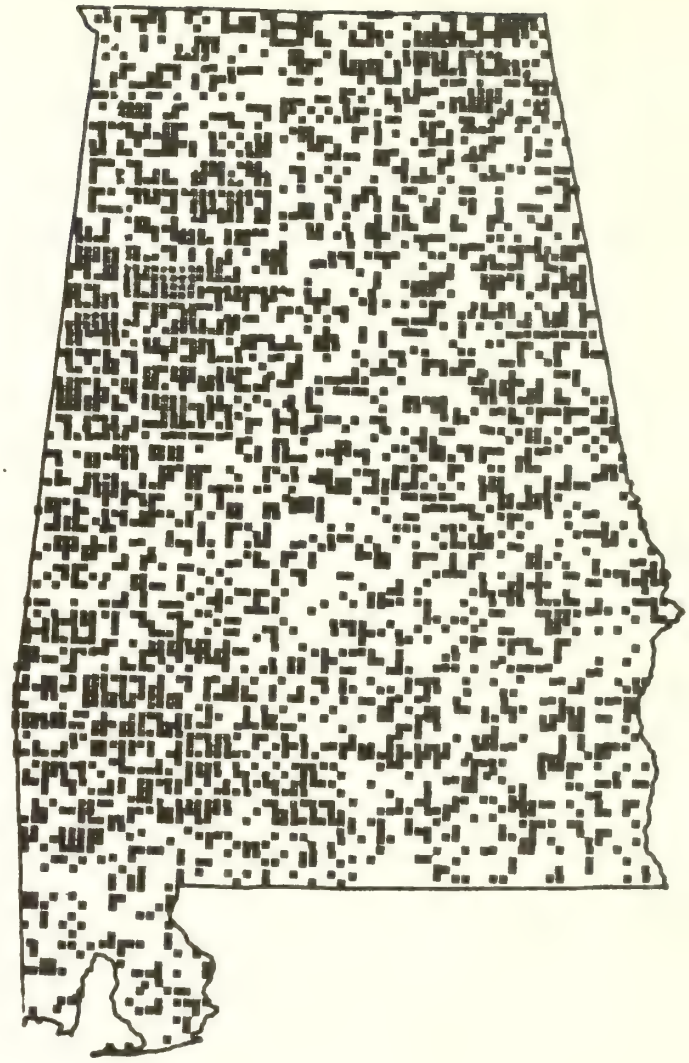

Figure 4.—*Distribution of hardwood biomass, each dot representing 300,000 tons woody green weight.*

weight while the North unit has the least amount of merchantable green weight.

All the inventory units were compared on the basis of the ratio of merchantable weight to residual weight. The Southwest-South unit has the highest merchantable to residual green weight ratio (1.17). The Southwest-North and West Central units follow closely (1.15 and 1.13 respectively) along with the Southeast and North Central units each at 1.00. The North unit has the lowest ratio (0.87) which can be attributed to the high concentration of hardwoods that contribute larger crowns, a higher proportion of rough and rotten trees, and higher sapling densities, all of which make up the residual weight component.

Forest inventory classifies forest stands on the basis of physiography: pine land, upland hardwood, and bottomland hardwood. These three major physiographic classes are not evenly proportioned in Alabama. Statewide, 18,121,100 acres are pine, 2,634,700 are bottomland hardwood, and 902,900 acres are upland hardwood. Eighty-nine percent of the acreage in the bottomland hardwood class lies south and west of the Fall Line. Seventy-eight percent of the upland hardwoods lie north and east of the Fall Line. The pine physiographic class is more evenly dispersed throughout the State with slightly higher concentrations southward.

As might be expected, biomass concentrations of physiographic classes closely adhere to the areal extent of the class. Eighty-nine percent of the bottomland hardwood biomass lies south and west of the Fall Line. Seventy-eight percent of the upland hardwood biomass lies north and east of the Fall Line. The bottomland hardwood and upland hardwood physiographic classes are almost totally hardwood with only 11 and 4 percent, respectively, in softwood biomass.

Statewide, biomass in the pine physiographic class is evenly proportioned between softwood and hard-

wood, 48 percent and 52 percent respectively. Regionally, the Southwest-South unit and the North unit are imbalanced between softwood and hardwood. The Southwest-South unit is composed of 66 percent pine and 34 percent hardwood. The North unit is 29 percent pine and 71 percent hardwood.

Concentrations of biomass on pine land, upland hardwoods, and bottomland hardwoods are 67, 86, and 95 tons per acre, respectively. The high biomass density of bottomland and upland hardwoods can be attributed to (1) higher weights of the crown portion, (2) higher productivity, especially on bottomland sites, and (3) the relatively older age for both groups as a whole (less cutting disturbance). Pine land has been greatly altered and disturbed by cutting, leaving such areas with a relatively younger age and/or lower stocking density. This results in considerably lower amounts of biomass per acre.

There are 2,779,100 acres of artificially regenerated forest stands in Alabama. The majority of these stands are in the southern part of the State with the highest concentration in the Southwest-South and Southwest-North units. Eighteen and 17 percent, respectively, of the timberland in these two units is artificially regenerated, slightly more than one out of every 5 acres.

Biomass on artificially regenerated forest land for the State is 119.9 million tons, about 44 tons per acre. This low amount of biomass per acre is attributed to artificially regenerated stands being predominantly pine, the relatively young age of most of the plantations, and selective exclusion of hardwoods. Statewide, plantations contribute only 8 percent of the total biomass. Plantations are 78 percent pine and 22 percent hardwood by weight.

By contrast, 1,431.3 million tons of biomass is in natural stands, slightly over 75 tons per acre. As expected, a significantly larger proportion of hardwood biomass occurs in natural stands than in artificially regenerated stands, 63 percent and 37 percent respectively. The Southwest-South unit contains the highest proportion of pine (48 percent) and the North unit has the lowest (18 percent).

Alabama is clearly an oak- and loblolly pine-dominated State. Fully 26 percent of the total State biomass is in oaks and 23 percent is in loblolly pine (fig. 5). This is 49 percent of the total State volume in the oak genus and loblolly pine species. In general, the oak proportion decreases toward the southern part of the State and the pine proportion decreases toward the north. The highest concentration of hardwoods in Alabama is in the North unit, the lowest in the Southwest-South unit, 65 and 28 tons per acre, respectively. The highest concentration of softwoods is in the Southwest-North unit and the lowest is in the North unit, 33 and 16 tons per acre respectively.

The *Quercus* genus is by far the dominant hardwood group in the State. At 402.1 million tons of woody biomass, it is approximately 3 times larger than its nearest competitor, sweetgum (fig. 6). The residual

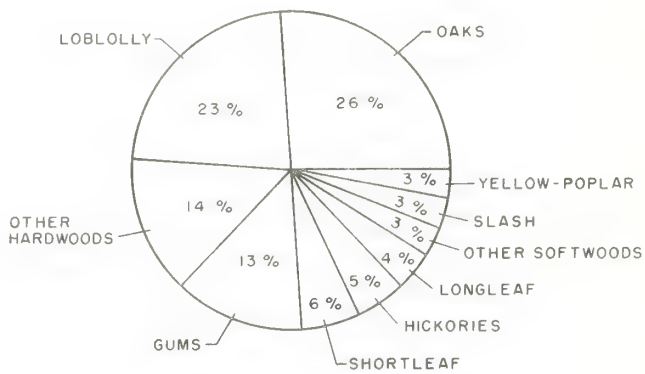

Figure 5.—*Percent of total Alabama woody biomass by species.*

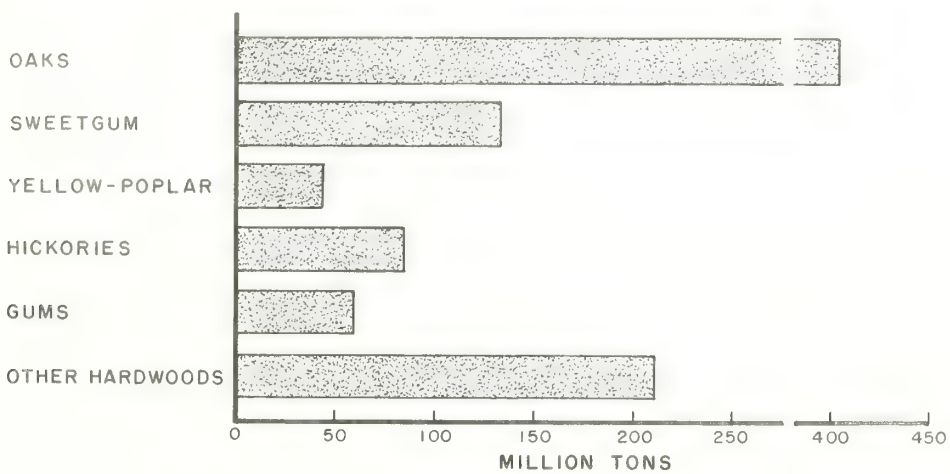

Figure 6.—*Hardwood woody biomass by species in Alabama.*

component of oak will play an important role in the availability of woody biomass. Sweetgum is the next major hardwood component of the Alabama forest ecosystem. At 133.0 million tons of woody biomass, it makes up 14 percent of all hardwoods and almost 9 percent of all woody biomass. Hickories are next, followed by gums and yellow-poplar. The *Nyssa* and *Carya* genera, along with sweetgum and yellow-poplar make up 321.2 million tons of woody biomass. These two genera and two species constitute more than the 211.7 million tons that the remaining 58 commercial and 19 noncommercial hardwood species contribute combined. The hardwood biomass is dominated by 5 genera in Alabama. Together they make up 77 percent of the total hardwood biomass in Alabama.

Of coniferous genera, *Pinus* is by far the dominant. Also recorded were *Chamaecyparis, Juniperus, Taxodium,* and *Tsuga.* In the latter conifers, only *Taxodium* contributed a significant amount to the woody biomass.

Loblolly pine, with 353.5 million tons of biomass, is the dominant conifer in the State and the dominant tree in the State (fig. 7). It is dominant in every unit except the Southwest-South unit where longleaf and slash pine are predominant.

Loblolly pine is more dominant than the entire oak genus in both the Southwest-North and Southeast units; in the West Central unit, it is co-dominant with the oak genus. The next dominant conifer, shortleaf pine, does not approach loblolly concentrations anywhere in the State. At 95.7 millions tons, it makes up only 16 percent of the softwood biomass. Slash and longleaf pine trail even farther behind and only make a significant contribution to total biomass in the Southwest-South unit.

Figure 8 illustrates the relationship between woody biomass and basal area. Basal area was also divided into eight classes to illustrate Alabama's woody biomass. Eighty-seven percent of the total woody biomass in Alabama is on timberland with a basal area of 60 square feet per acre or higher. Furthermore, 17 percent of the total woody biomass is on timberland with a basal area greater than 140 square feet per acre, meaning that 17 percent of the State's total woody biomass is on 8 percent of all timberland. By contrast, lower density stands (less than 60 square feet per acre) account for 12 percent of the State's biomass but occupy 34 percent of total timberland. It should be noted that not all the low density acreage is understocked but includes lands in the regeneration phase after harvest.

There are 7,458,400 acres below and 3,508,300 acres above the optimum management range of 60 to 120 square feet per acre. Slightly over one-half, 863.2 million tons, of Alabama's biomass is on forest land with optimum stocking. Lands that are theoretically overstocked could be thinned of approximately 175.4 million tons (estimation based on decreasing biomass by a conservative 50 tons per acre resulting from decreasing basal area 50 square feet on 3,508,700 acres from 133 to 83 square feet per acre).

A total of 15,973,220 acres of Alabama's timberland is classed as mixed-age. Of the remaining 5,685,600 even-aged acres, 2,779,100 are artificially regenerated. Of the 299.6 million tons of biomass in even-aged stands, 203.8 million tons are softwood, 68 percent of the total. The remaining 1,251.6 million tons in mixed-age stands are heavily dominated by hardwood, 839.2 million tons or 67 percent.

Alabama's hardwood biomass is fairly evenly distributed across the range of size classes (fig. 9). A total of 189.7 million tons of biomass is in the 1.0- to 4.9-inch size class, 20 percent of the State's hardwood biomass. In contrast, very little of the softwood biomass is in the 1.0- to 4.9- and the 15.0-inch and larger size classes. Sixty-nine percent of the softwood biomass is in the 5.0- to 14.9-inch range of diameters.

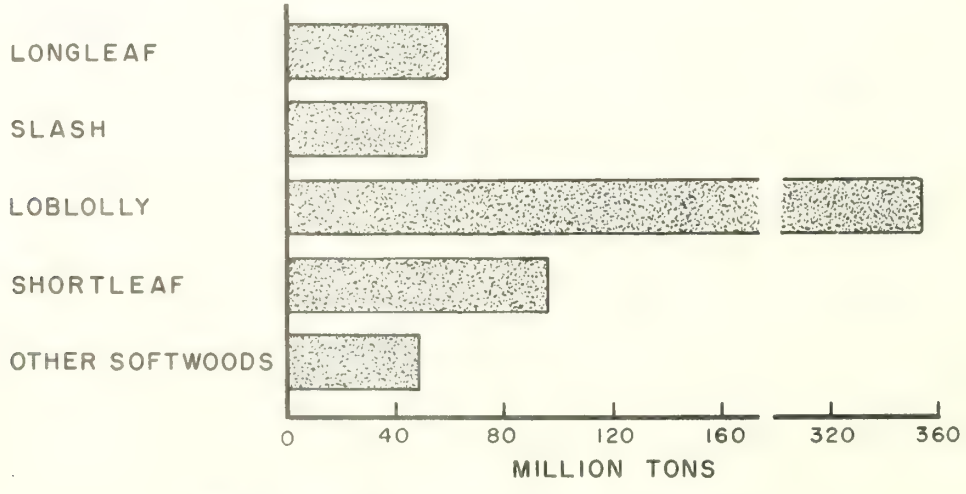

Figure 7.—*Softwood woody biomass by species in Alabama.*

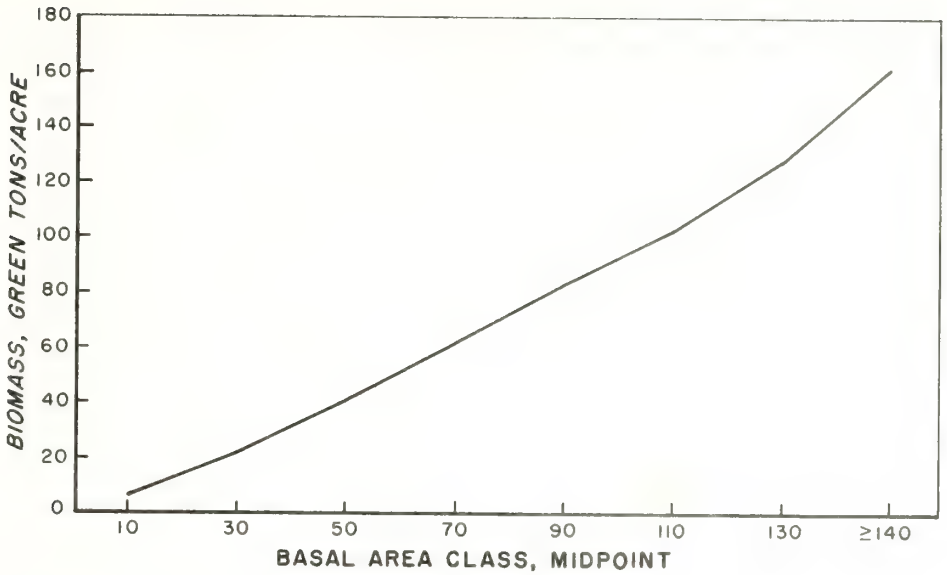

Figure 8.—*Relationship of woody biomass to basal area in Alabama.*

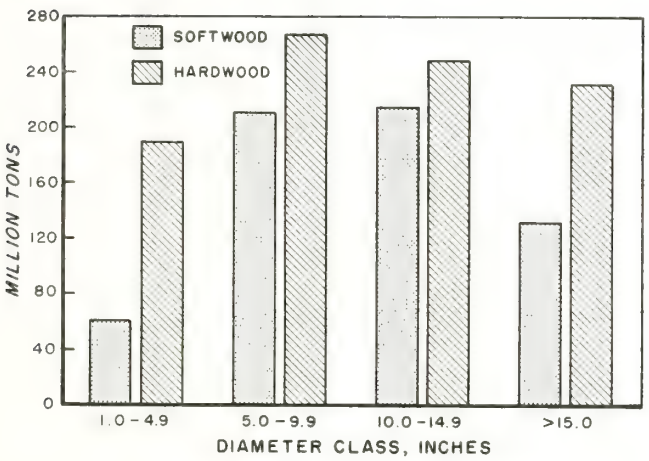

Figure 9.—*Woody biomass by broad diameter classes in Alabama.*

OWNERSHIP

The major proportion of Alabama's woody biomass is on nonindustrial private land. On such lands, 698.9 million tons of total woody biomass is in miscellaneous private ownership and 444.6 million tons is in farm ownership (fig. 10). Together, this is 74 percent of the total woody biomass resource. The next sizeable holdings of biomass are forest industry (20 percent of the resource) followed by public holdings (6 percent of the resource). Most of the hardwood biomass is on nonindustrial private land. A total of 719.5 million tons is on such lands, 77 percent of the State's hardwood biomass. Likewise, 424.1 million tons of softwood biomass is in nonindustrial private ownership, 69 percent of total softwood biomass.

The nonindustrial privately-owned biomass is proportionately highest in the northern portion of the State, in particular the North and North Central units and also in the Southeast unit. The amount of biomass on private land is higher than forest industry or public land in every survey unit. In relation to nonindustrial private biomass volume, forest industry biomass holdings are proportionately highest in the Southeast-South, Southeast-North, and West Central survey units. Public-owned biomass is most significant in the North, North Central, and West Central units. Even so, in the North Central and North units, public-owned biomass is still only 12 percent and 11 percent, respectively, of the 2 units total biomass.

The residual biomass is also highest on nonindustrial private land, 566.2 million tons (75 percent of the State total residual and 36 percent of the total State biomass weight). Seventy-three percent of the State's merchantable biomass is also on nonindustrial private land. It is clear that future interest in biomass availability and procurement will involve the status of private owners.

Biomass concentrations are lowest on nonindustrial private land, 69 tons per acre. Forest industry follows with public ownership highest, 81 and 86 tons per acre respectively. It is evident when looking at hardwood and softwood concentrations that the primary differences between nonindustrial private ownership versus forest industry and public ownership is the difference in softwood biomass. Forest industry manages most intensively for pine and produces softwood concentrations of 40 tons per acre. Public ownership also manages for pine, but much of other public ownership is in bottomland areas comprised mostly of older hardwood stands. This results in public owner-

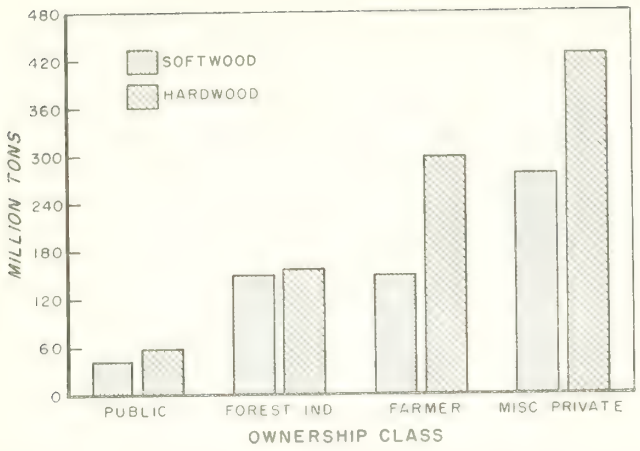

Figure 10.—*Woody biomass by major ownership category in Alabama.*

ship being high in concentrations of both softwood and hardwood biomass, 36 and 50 tons per acre, respectively. Nonindustrial private lands, while nearly equivalent to forest industry and public ownership in hardwood concentrations, rank far below in softwood concentrations. Farm lands are lowest, 23 tons per acre, with miscellaneous private ownerships not faring much better, 27 tons per acre. The primary reasons for low softwood concentrations are selective cutting of pine, leaving non-utilized hardwoods standing, and taking no steps to ensure the re-establishment of pine.

As management activity intensifies in a stand, the level of residual biomass decreases. Since biomass users in industrial concerns cannot compete with lumber and pulp industries for merchantable material, this could become an important consideration since biomass collection will primarily be from residual material remaining on site after removal of merchantable material. In Alabama, the ratio of merchantable to residual biomass on nonindustrial private land is 1.02. Forest industry land has a merchantable to residual ratio of 1.12 and public land has a ratio of 1.15.

FOREST TYPE

Statewide, softwood and hardwood biomass totals are highest in the loblolly-shortleaf and oak-hickory forest types (fig. 11). The loblolly-shortleaf type contains 55 percent of the total softwood biomass in the State. The oak-hickory type contains 46 percent of the State's hardwood biomass. The softwood biomass in the loblolly-shortleaf type is most prominent in the Southwest-North, Southeast, West Central, and North Central units. Hardwood biomass in the oak-hickory type is most prominent in the Southeast, West Central, and North Central units.

Residuals for softwood are highest in the loblolly-shortleaf type, 109.8 million tons. Hardwood residuals are highest in the oak-hickory, oak-gum-cypress, and oak-pine types, at 256.3, 119.8, and 109.9 million tons, respectively.

Highest biomass concentrations are in the oak-gum-cypress forest type, 95 tons per acre. This is due to the older age and higher productivity of these stands that virtually have no softwoods. Only 6 percent of the biomass per acre is softwood. The concentration of biomass in the loblolly-shortleaf type follows at 75 tons per acre, 77 percent of which is softwood. Biomass density for the longleaf-slash, oak-pine, and oak-hickory forest types are next at 63, 66,

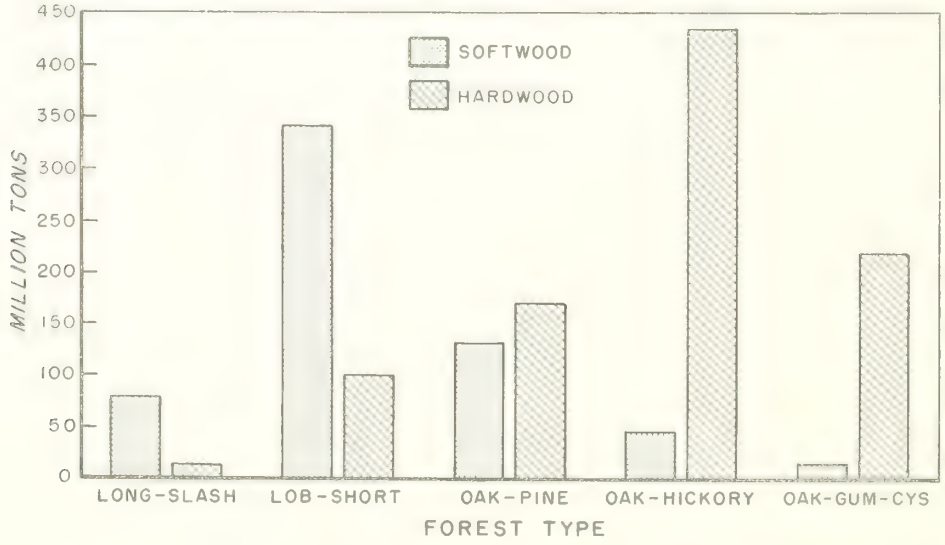

Figure 11.—*Woody biomass by major forest type in Alabama.*

and 66 tons per acre, respectively. Only the oak-pine type is fairly evenly distributed with 44 percent softwood and 56 percent hardwood. All of the other types are heavily skewed either to softwood or hardwood.

Of significance is the amount of rough and rotten tree biomass in the oak-hickory forest type, 85.7 million tons. This is 39 percent of the total rough and rotten biomass. Statewide, there are 12 tons per acre of rough and rotten biomass in the oak-hickory forest type and the 18 tons per acre of rough and rotten biomass in the oak-gum-cypress forest type.

HARVESTING

The Alabama inventory process documented harvesting practices on 18,121,100 acres. This acreage is on upland sites where pine is present or was formerly present. Harvesting information was not collected on 903,000 acres of upland hardwood and 2,634,700 acres of bottomland hardwood sites.

Of these 18,121,100 acres documented, 6,271,400 had some form of cutting practice applied between 1972 and 1982. This includes all types of cutting, from single tree selection to complete clearcuts. Partial cutting accounts for a big portion of harvested acreage, 2,858,800 acres. These harvests include seed tree, strip cutting, shelterwood, group selection, and single tree selection. Slightly over 60 percent of the partial harvest acreage is in the single tree selection category, 1,739,100 acres. It should be noted that single tree selection in the southern States is usually not practiced as a silvicultural tool in the traditional sense but is commonly applied to harvest certain trees without thought of regeneration or stand perpetuation. These cut trees are usually harvested (by nonindustrial private owners) in regard to economics or immediate use (firewood); and in this sense, with increasing intensity, may overlap other partial harvest methods such as diameter limit cut, shelterwood cut, or group selection.

Since field crews only visit the permanent sample plots at a specific point in time, it is not always easy for them to assess the actual harvest system that was applied to the area or to even tell if the site was whole-tree logged or if only merchantable material was removed.

Biomass estimates for harvested trees were predicted in a slightly different manner than live trees on nonharvested acreage. First, total green weight biomass was estimated prior to cutting. This included cut trees, standing trees, commercial and noncommercial trees, rough and rotten trees, saplings, and trees that were knocked down. Trees that were cut were given a predicted diameter based on the time since last inventory up until the time they were cut. Biomass was then predicted using a diameter-only equation since total height was not recorded during the prior inventory. Next, the weight of merchantable section of cut trees was calculated. Finally, the residual of harvested plots was estimated. Residual includes all trees >=1.0-inch that were left standing or were knocked down and the tops and unused portions of all cut trees. Included are cull and noncommercial species. The merchantable section includes the weight of the utilized portion of all cut trees. This includes the stem up to a 4.0-inch merchantable top.

Timberland that was clearcut in Alabama between 1972 and 1982 yielded woody biomass that averaged 95 tons per acre before cutting. Of this, 52 tons per acre was in softwood biomass and 43 tons per acre in hardwood. Timberland that was partially cut averaged 105 tons per acre before cutting operations. On these lands, softwoods averaged 57 tons per acre while hardwoods averaged 48 tons per acre.

One of the most intense forms of cutting application is the clearcut. In Alabama, there were 2,482,200 acres cut in this manner. The highest concentration of clearcutting was in the North Central unit where 15 percent of total timberland was subjected to a cut. The West Central unit was next highest at 13 percent, followed by the Southwest-North and Southeast units, both at 12 percent of timberland being clearcut.

Of most interest is the residual green weight of biomass material left on these lands after clearcutting. A total of 132.2 million tons of crowns and nonutilized material (standing or knocked down) remained after 103.8 million tons of merchantable biomass were cut and removed. The West Central unit has the highest total residual, 59 tons per acre. It is interesting to note that the residual weights on these clearcut lands approaches the State average for total green biomass of 71.6 tons per acre.

The highest softwood residual concentration was in the West Central unit, followed closely by the Southwest-South unit. Excluding the North unit, which naturally has the lowest concentration of softwood, the range of softwood biomass residual was from 23 to 29 tons per acre for the remaining 5 units.

The Southeast and North units both had hardwood residual concentrations of 33 tons per acre, the highest for the State. The lowest hardwood residual was in the Southwest-South unit where softwoods clearly outrank hardwood concentrations. Excluding the Southwest-South unit, the range of residual concentrations was 26 to 33 tons per acre.

Overall, clearcutting as practiced in the State leaves similar residuals in all regions. The amount of total biomass residual remaining on clearcut lands differs by no more than 10 tons per acre between inventory units. The ratio of removed merchantable to residual for total biomass is 1.27. For softwoods, the ratio is 0.88 and for hardwoods it's 2.03. Obviously, the utilization of softwoods, because of morphology and economics, is much higher than hardwoods.

Because of potential practical application for a biomass harvest after merchantable material is removed, biomass on clearcut pine upland sites is reported in two classes: material left alive and standing, and material that was either cut and left on the gound or knocked down in the process of the cutting operation. Retrieval of biomass material that is left on the ground may not be economically feasible, currently, due to equipment limitations and labor intensity.

The amount of standing material left on clearcut pine upland sites averages only 10 tons per acre, Statewide. This is 24 percent of the total residual left on site. Downed biomass averages 42 tons per acre Statewide. For both downed and standing biomass, 50 percent is softwood and 50 percent is hardwood.

The major quantitative difference between clearcuts and partial harvests is the proportion of merchantable material removed. On partially cut lands, 23 percent of the merchantable portion of biomass was cut and removed. On clearcut lands, 44 percent of the merchantable portion of biomass was removed. This results in different quantities and tree classes of biomass remaining after different cutting operations, with partial cut timberland containing varying amounts of merchantable trees in the remaining standing tree population. Only a conjectural estimate can be made of available material for biomass utilization on these partial cut lands because degrees of cutting range so broadly. One possible way to estimate the biomass residual on such lands is to use the same proportion of merchantable material removed, as on clearcut land, and subtract this difference from the current residual. Using the combined proportion of 44 percent for the State (53 percent softwood, 33 percent hardwood), yields 76.2 million tons of residual softwood biomass and 91.6 million tons of residual hardwood biomass, Statewide, on partial cut lands. There are many considerations in collecting residual biomass on these lands such as considering the damage to saplings and pole-size growing-stock trees of the future stand. Another consideration is the varying concentrations of this residual; adequate quantities per acre must be present for a biomass harvesting operation to be feasible.

On timberland that had any form of cutting operation, an estimate can be made of the total residual biomass. A total of 174.3 million tons of residual softwood and 201.4 million tons of residual hardwood biomass were left on upland timberland between 1972 and 1982 (using above adjustment on partial cut timberland). This is approximately 174.4 and 201.5 hundred thousand tons per year average for the State. A realistic estimate would most likely be much less as consideration must be allowed for maintenance of forest site conditions such as soil productivity, organic matter content of soil, nutrient availability, degree of soil disturbance during cutting practices, and slope of land. Any of these conditions, or others, would dictate removing far less or no residual from the forest stand. High soil temperatures, especially in the south, necessitates leaving some material for organic matter refurbishment.

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Appendix

RELIABILITY OF THE DATA

Reliability of the estimates is subject to errors in measurement of individual trees and sampling errors. Tree measurements for biomass estimation are diameter at breast height (d.b.h.) and total height for trees equal to or greater than 5.0 inches d.b.h., and d.b.h. alone for trees smaller than 4.9 inches, mortality trees, and cut trees. Errors in individual tree biomass derive from application of these measurements in biomass equations developed by Clark (1985). They were examined in the analyses but are not reported here. Sampling error is amenable to mathematical evaluation for probability of error. Sampling errors reported here are based on one standard deviation. That is, the probability is two out of three that the values reported here would have been within the limits reported of the true total value.

Estimates for county totals are presented. Aggregate error for more than a single county or for other subsamples may be obtained by applying the formula:

$$SEG = \frac{SET\sqrt{XT}}{\sqrt{XG}}$$

where

SEG = Standard error (SE) of the estimate for the group of counties in percent.

SET = SE of estimate for the State total in percent.

XT = State total for component of interest (total, merchantable or residual).

XG = Total for group of counties.

The first 5 counties of table 37 have been grouped to illustrate the computation of softwood residual biomass standard error percent.

XT = 1911.6 (Hundred thousand tons)

XG = 180.4 (Hundred thousand tons)

SET = 2.1 Percent (table 38)

$$SEG = \frac{2.1\sqrt{1911.6}}{\sqrt{180.4}}$$

SEG = 6.8 Percent

Hence, weight of softwood residual biomass in the 5 counties lies between 168.8 and 192.7 with a probability of two chances out of three.

DEFINITIONS

Biomass Types

Biomass, Woody—The amount of live organic material in woody vegetation. Included is bark and wood; excluded is fruits, flowers, leaves, stump, and roots.

Merchantable Green Weight—Fresh weight of woody biomass of all growing stock trees greater than 5.0 inches d.b.h. from a 1-foot stump to a 4.0-inch diameter outside bark (d.o.b.) or to a point prior to reching a 4.0-inch d.o.b. because of branching, forking, rot, or other factors which would exclude the bole from merchantability.

Residual Green Weight—Fresh weight of woody biomass of the nonmerchantable portion of all growing-stock trees greater than or equal to 5.0 inches d.b.h., all saplings, all noncommercial trees, and all rough and rotten trees.

Total Green Weight—Fresh weight of woody biomass for all live woody vegetation greater than or equal to 1.0-inch d.b.h.. Included are growing-stock, commercial, noncommercial, and rough and rotten (sound portion) trees.

Tree Classes

Commercial Species—Tree species currently or prospectively suitable for industrial wood products. Excluded are noncommercial species such as blackjack oak and blue beech.

Noncommercial Species—Tree species of typically small size, poor form, or inferior quality which normally do not develop into trees suitable for industrial wood products.

Growing-Stock Trees—Live trees of commercial species classified as sawtimber, poletimber, sapling, and seedlings. Rough and rotten trees are excluded.

Rough Trees—Live trees of commercial species that are unmerchantable for saw logs currently or potentially because of roughness or poor form. Also included are all live trees of noncommercial species.

Rotten Trees—Live trees of commercial species that are unmerchantable for saw logs currently or potentially because of rot.

Saplings—Live trees 1.0 to 4.9 inches in diameter.

Hardwoods—Dicotyledonous trees, usually broad-leaved and deciduous.

Softwoods—Coniferous trees, usually evergreen, having needle or scale-like leaves.

Forest Types

Longleaf-Slash Pine—Forests in which longleaf or slash pine, singly or in combination, comprise a plurality of the stocking. Common associates include other southern pines, oak, and gum.

Loblolly-Shortleaf Pine—Forests in which pine and eastern redcedar (except longleaf or slash pine), singly or in combination, comprise a plurality of the stocking. Common associates include oak, hickory, and gum.

Oak-Pine—Forest in which hardwoods (usually upland oaks) comprise a plurality of the stocking, but in which softwoods, except cypress, comprise 25 to 50 percent of the stocking. Common associates include yellow-poplar, elm, maple, and black walnut.

Oak-Gum-Cypress—Bottomland forest in which tupelo, blackgum, sweetgum, oaks, or cypress, singly or in combination, comprise a plurality of the stocking except where pines comprise 25 to 50 percent, in which case the stand would be classified oak-pine. Common associates include cottonwood, willow, ash, elm, hackberry, and maple.

Elm-Ash-Cottonwood—Forests in which elm, ash, or cottonwood, singly or in combination, comprise a plurality of the stocking. Common associates include willow, sycamore, beech, and maple.

Ownership Classes

Public—Forest land which is under jurisdiction of Federal, State, County, or Municipal government and is not withdrawn from timber utilization.

Forest Industry—Forest land owned by companies or individuals operating wood-using plants.

Farmer—Forest land owned by individuals, corporations, or companies whose income from agricultural products (excluding wood products) is greater than 1,000 dollars annually.

Miscellaneous Private—Forest land owned by individuals, corporations, or companies who do not operate wood-using plants and do not have a farm income greater than 1,000 dollars annually.

Miscellaneous Definitions

Timberland—Forest land at least 16.7 percent stocked by forest trees of any size, or formerly having such tree cover, and not currently developed for nonforest uses. This land must be greater than or equal to 1 acre, be producing or capable of producing crops of industrial wood (minimum 20 cubic feet per acre per year), and not be withdrawn from timber utilization. Timberland is synonymous with "Commercial Forest Land" in prior usage.

Basal Area—The area in square feet of the cross section at breast height of a single tree or of all the trees in a stand, usually expressed in square feet per acre.

D.b.h. (Diameter at breast height)—Tree diameter in inches, outside bark, measured at 4.5 feet above ground level.

D.o.b. (Diameter outside bark)—Stem diameter in inches, outside bark, measured at various points along the bole.

SPECIES LIST

Scientific and common names of species that occur in the Midsouth States[1]

Genus	Species	Common name
Commercial Species		
Softwoods		
Abies	*balsamea*	balsam fir
	fraseri	Fraser fir
Chamaecyparis	*thyoides*	Atlantic white-cedar
Juniperus	*silicicoloa*	southern redcedar
	virginiana	eastern redcedar
Picea	*mariana*	black spruce
	rubens	red spruce
Pinus	*clausa*	sand pine
	echinata	shortleaf pine
	elliottii	slash pine
	glabra	spruce pine
	palustris	longleaf pine
	ponderosa	ponderosa pine
	pungens	Table Mountain pine
	rigida	pitch pine
	serotina	pond pine
	strobus	eastern white pine
	taeda	loblolly pine
	virginiana	Virginia pine
Taxodium	*distichum* var. *distichum*	baldcypress
	distichum var. *nutans*	pondcypress
Thuja	*occidentalis*	northern white-cedar
Tsuga	*canadensis*	eastern hemlock
	caroliniana	Carolina hemlock
Hardwoods		
Acer	*barbatum*	Florida maple
	negundo	boxelder
	nigrum	black maple
	rubrum	red maple
	saccharinum	silver maple
	saccharum	sugar maple
Aesculus	*glabra*	Ohio buckeye
	octandra	yellow buckeye
Betula	*alleghaniensis*	yellow birch
	lenta	sweet birch
	nigra	river birch
	populifolia	gray birch
Carya	sp.	hickory
	aquatica	water hickory
	illinoensis	pecan
Castanea	*dentata*	American chestnut
	pumila	Allegheny chinkapin
Catalpa	sp.	catalpa
Celtis	*laevegata*	sugarberry
	occidentalis	hackberry
Cornus	*florida*	flowering dogwood

SPECIES LIST

Scientific and common names of species that occur in the Midsouth States[1]—Continued

Genus	Species	Common name
Diospyros	*virginiana*	common persimmon
Fagus	*grandifolia*	American beech
Fraxinus	*americana*	white ash
	nigra	black ash
	pennsylvanica	green ash
	profunda	pumpkin ash
	qradrangulata	blue ash
Gleditsia	*aquatica*	water locust
	triacanthos	honey locust
Gymnocladus	*dioicus*	Kentucky coffeetree
Halesia	*carolina*	Carolina silverbell
Ilex	*opaca*	American holly
Juglans	*cinerea*	butternut
	nigra	black walnut
Liquidambar	*styraciflua*	sweetgum
Liriodendron	*tulipifera*	yellow-poplar
Maclura	*pomifera*	Osage-orange
Magnolia	*acuminata*	cucumbertree
	grandiflora	southern magnolia
	virginiana	sweetbay
Morus	*rubra*	red mulberry
Nyssa	*aquatica*	water tupelo
	ogeche	Ogeechee tupelo
	sylvatica var. *sylvatica*	black tupelo, blackgum
	sylvatica var. *biflora*	swamp tupelo
Persea	*borbonia*	redbay
Platanus	*occidentalis*	American sycamore
Populus	sp.	cottonwood
Prunus	*serotina*	black cherry
Quercus	*alba*	white oak
	bicolor	swamp white oak
	coccinea	scarlet oak
	durandii	Durand oak
	falcata var. *falcata*	southern red oak
	falcata var. *pagodifolia*	cherrybark oak
	imbricaria	shingle oak
	laurifolia	laurel oak
	lyrata	overcup oak
	macrocarpa	bur oak
	michauxii	swamp chestnut oak
	muehlenbergii	chinkapin oak
	nigra	water oak
	nuttallii	Nuttall oak
	palustris	pin oak
	phellos	willow oak
	prinus	chestnut oak
	rubra	northern red oak
	shumardii	Shumard oak
	stellata var. *stellata*	post oak
	stellata var. *paludosa*	Delta post oak
	velutina	black oak

SPECIES LIST

Scientific and common names of species that occur in the Midsouth States[1]—Continued

Genus	Species	Common name
Robinia	*pseudoacacia*	black locust
Salix	sp.	willow
Sassafrass	*albidum*	sassafras
Tilia	*americana*	American basswood
	heterophylla	white basswood
Ulmus	*alata*	winged elm
	americana	American elm
	crassifolia	cedar elm
	pumila	Siberian elm
	rubra	slippery elm
	serotina	September elm
	thomassii	rock elm
Noncommercial Species		
Amelanchier	sp.	serviceberry
Aesculus	sp.	buckeye
Ailanthus	*altissima*	ailanthus, tree-of-heaven
Bumelia	sp.	chittamwood, gum bumelia
Carpinus	*caroliniana*	bluebeech, American hornbeam
Cercis	*canadensis*	eastern redbud
Cotinus	*obovatus*	smoketree
Crataegus	sp.	hawthorn
Magnolia	*macrophylla*	bigleaf magnolia
Malus	sp.	apple
Melia	*azedarach*	chinaberry
Morus	*alba*	white mulberry
Ostrya	*virginiana*	eastern hophornbeam, ironwood
Oxydendrum	*arboreum*	sourwood
Planera	*aquatica*	water-elm
Prosopis	sp.	mesquite
Prunus	sp.	plums, cherries
Quercus	*incana*	bluejack oak
	laevis	turkey oak
	marilandica	blackjack oak
	virginiana	live oak
Vaccinium	*arboreum*	sparkleberry

[1]Names according to: Little, Elbert L., Jr. *Checklist of United States Trees (Native and Nautralized)*. 1978, U.S. Dep. Agr. Handbook No. 541, 375 p.

TABLES

1.—Green weight of woody biomass by component 19
2.—Area of timberland and green tons per acre of total woody biomass 19
3.—Area of timberland by physiographic class 19
4.—Green weight of total woody biomass by physiographic class 19
5.—Green weight of total woody biomass by stand origin 19
6.—Green weight of total softwood, woody biomass by age class 20
7.—Green weight of total hardwood, woody biomass by age class 20
8.—Green weight of total woody biomass of all trees greater than 1.0 inch by size class 20
9.—Green weight of merchantable woody biomass by size class of trees greater than 5.0 inches 20
10.—Green weight of residual biomass by size class of trees greater than 5.0 inches 21
11.—Green weight of rough and rotten woody biomass by size class of trees greater than 5.0 inches 21
12.—Green weight of total woody biomass by softwood species groups 21
13.—Green weight of total woody biomass by hardwood species groups 21
14.—Area of timberland by basal area class 22
15.—Green weight of total woody biomass by basal area class 22
16.—Green weight of merchantable woody biomass by basal area class 22
17.—Green weight of residual woody biomass by basal area class 22
18.—Green weight of rough and rotten woody biomass by basal area class 23
19.—Green weight of sapling woody biomass by basal area class 23
20.—Green weight of total woody biomass by ownership 23
21.—Green weight of merchantable woody biomass by ownership 23
22.—Green weight of residual woody biomass by ownership 24
23.—Green weight of rough and rotten woody biomass by ownership 24
24.—Green weight of sapling woody biomass by ownership 24
25.—Green weight of total woody biomass by forest type 24
26.—Green weight of merchantable woody biomass by forest type 25
27.—Green weight of residual woody biomass by forest type 25
28.—Green weight of rough and rotten woody biomass by forest type 25
29.—Green weight of sapling woody biomass by forest type 25
30.—Total woody biomass by species component and group 26
31.—Area of timberland harvested by type of harvest 26
32.—Green weight of woody biomass on clearcut, pine upland 26
33.—Green weight of woody biomass on partial cut, pine upland 27
34.—Green weight of woody biomass on diameter-limit cut, pine upland 27
35.—Green weight of woody biomass on salvage cut, pine upland 27
36.—Woody biomass remaining after clearcut operation on pine upland, by standing live and downed biomass 28
37.—Green weight of woody biomass by county and species component 28
38.—Sampling errors for green woody biomass components by county 29
39.—Sampling errors for green woody biomass components by unit 31

Table 1.—*Green weight of woody biomass by component,[1] Alabama, 1982*

Forest survey unit	Total green weight	Merchantable green weight	Residual green weight
	Million tons		
Southwest-South	169.3	91.3	78.1
Southwest-North	264.2	141.3	122.9
Southeast	366.3	183.6	182.7
West Central	256.9	136.4	120.6
North Central	317.2	158.9	158.3
North	177.3	82.4	94.9
State	1,551.2	793.8	757.5

[1]Totals may not add due to rounding.

Table 2.—*Area of timberland and green tons per acre of total woody biomass,[1] Alabama, 1982*

Forest survey unit	Thousand acres	Tons/acre
Southwest-South	2,858.2	59.3
Southwest-North	3,382.5	78.1
Southeast	5,415.8	67.6
West Central	3,272.1	78.5
North Central	4,542.6	69.8
North	2,187.7	81.0
State	21,658.8	71.6

[1]Totals may not add due to rounding.

Table 3.—*Area of timberland by physiographic class,[1] Alabama, 1982*

Forest survey unit	Pine	Upland hardwood	Bottomland hardwood
		Thousand acres	
Southwest-South	2,238.3	12.3	607.6
Southwest-North	2,741.9	78.2	562.4
Southeast	4,676.5	84.6	654.6
West Central	2,734.1	23.3	514.7
North Central	4,286.4	112.1	144.1
North	1,443.9	592.5	151.3
State	18,121.1	902.9	2,634.7

[1]Totals may not add due to rounding.

Table 4.—*Green weight of total woody biomass by physiographic class,[1] Alabama, 1982*

Forest survey unit	Pine		Upland hardwood		Bottomland hardwood	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
			Hundred thousand tons			
Southwest-South	783.9	372.8	0.0	14.8	112.4	409.5
Southwest-North	1,050.8	921.2	4.0	68.4	54.7	543.2
Southeast	1,480.3	1,533.3	4.1	59.4	35.6	550.2
West Central	956.3	1,057.5	2.0	21.1	25.9	506.6
North Central	1,290.8	1,681.7	5.9	92.3	2.8	98.3
North	322.8	790.0	17.1	480.5	13.0	149.0
State	5,884.7	6,356.5	33.1	736.4	244.4	2,256.8

[1]Totals may not add due to rounding.

Table 5.—*Green weight of total woody biomass by stand origin,[1] Alabama, 1982*

Forest survey unit	Natural stands			Artificially regenerated stands		
	Total	Softwood	Hardwood	Total	Softwood	Hardwood
			Hundred thousand tons			
Southwest-South	1,491.0	726.1	764.9	202.3	170.1	32.2
Southwest-North	2,427.0	947.8	1,479.2	215.2	161.7	53.5
Southeast	3,365.1	1,268.7	2,096.4	298.7	251.2	47.5
West Central	2,352.6	819.1	1,533.5	215.5	165.0	50.5
North Central	2,986.1	1,167.4	1,818.7	186.6	132.1	54.5
North	1,691.0	299.0	1,392.0	81.4	53.9	27.5
State	14,312.8	5,228.1	9,084.7	1,199.7	934.0	265.7

[1]Totals may not add due to rounding.

Table 6.—*Green weight of total softwood, woody biomass by age class,[1] Alabama, 1982*

Forest survey unit	Age class (midpoint)									
	5	15	25	35	45	55	65	75	85[2]	Mixed
	Hundred thousand tons									
Southwest-South	16.5	63.3	58.6	65.5	47.4	45.4	18.5	5.6	0.0	575.4
Southwest-North	18.1	64.5	65.8	51.0	8.6	16.3	6.6	0.0	0.0	878.6
Southeast	18.2	115.9	130.0	209.7	40.1	27.1	6.1	0.0	0.0	972.8
West Central	14.2	23.9	168.6	128.7	74.0	34.8	4.4	8.6	0.0	526.8
North Central	17.6	30.3	119.1	121.6	29.8	26.1	25.4	0.0	0.0	929.6
North	1.9	22.5	32.5	16.2	21.4	13.7	0.0	3.4	0.3	241.1
State	86.5	320.5	574.6	592.6	221.3	163.4	61.1	17.7	0.3	4,124.4

[1]Totals may not add due to rounding.
[2]Includes 80 years and over.

Table 7.—*Green weight of total hardwood, woody biomass by age class,[1] Alabama, 1982*

Forest survey unit	Age class (midpoint)									
	5	15	25	35	45	55	65	75	85[2]	Mixed
	Hundred thousand tons									
Southwest-South	9.8	8.5	21.4	21.1	25.6	25.0	9.8	0.0	0.0	676.4
Southwest-North	13.5	25.4	15.8	9.9	10.5	6.6	1.8	0.0	7.7	1,441.5
Southeast	18.0	33.1	43.9	124.5	16.3	10.4	2.9	0.0	0.0	1,893.8
West Central	10.5	8.7	30.8	53.7	41.4	33.6	3.9	3.4	0.0	1,399.1
North Central	14.9	19.3	36.5	39.3	33.5	9.1	4.9	13.0	0.0	1,701.9
North	6.4	8.0	13.7	52.5	13.1	10.6	0.0	10.3	25.4	1,279.5
State	73.0	103.1	162.1	301.0	140.3	95.3	23.4	26.8	33.0	8,392.1

[1]Totals may not add due to rounding.
[2]Includes 80 years and over.

Table 8.—*Green weight of total woody biomass of all trees greater than 1.0 inch by size class,[1] Alabama, 1982*

Forest survey unit	1.0–4.9		5.0–9.9		10.0–14.9		≥15.0	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons							
Southwest-South	107.3	187.5	300.5	228.0	327.7	189.8	160.8	192.2
Southwest-North	84.8	298.9	306.3	425.9	405.9	352.6	312.5	455.4
Southeast	147.1	462.6	481.1	630.0	519.9	580.7	371.9	469.7
West Central	86.2	299.2	366.2	456.8	336.9	439.7	194.9	389.5
North Central	141.7	423.3	507.4	566.3	428.0	497.1	222.5	385.6
North	38.8	225.8	144.2	357.7	117.4	419.4	52.6	416.6
State	605.8	1,897.2	2,105.7	2,664.7	2,135.8	2,479.3	1,315.1	2,308.9

[1]Totals may not add due to rounding.

Table 9.—*Green weight of merchantable woody biomass by size class of trees greater than 5.0 inches,[1] Alabama, 1982*

Forest survey unit	5.0–9.9		10.0–14.9		≥15.0	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons					
Southwest-South	222.9	127.1	268.8	94.6	125.1	74.1
Southwest-North	219.8	244.2	324.2	200.2	242.7	181.7
Southeast	335.2	350.6	398.9	303.6	268.0	179.2
West Central	275.4	255.7	276.9	245.2	153.3	157.2
North Central	378.5	307.7	350.1	246.5	173.3	133.1
North	103.8	205.7	95.4	223.5	38.5	156.8
State	1,535.6	1,491.0	1,714.3	1,313.6	1,000.9	882.1

[1]Totals may not add due to rounding.

Table 10.—*Green weight of residual biomass by size class of trees greater than 5.0 inches,*[1] *Alabama, 1982*

Forest survey unit	5.0–9.9		10.0–14.9		≥15.0	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons					
Southwest-South	77.6	100.9	58.9	95.2	35.7	118.1
Southwest-North	86.6	181.7	81.7	152.4	69.7	273.7
Southeast	145.9	279.4	121.0	277.1	103.9	290.5
West Central	90.8	201.1	60.0	194.4	27.7	232.3
North Central	128.9	258.6	77.9	250.6	49.2	252.5
North	40.3	152.0	22.0	195.9	14.2	259.8
State	570.2	1,173.7	421.5	1,165.7	300.4	1,426.9

[1]Totals may not add due to rounding.

Table 11.—*Green weight of rough and rotten*[1] *woody biomass by size class of trees greater than 5.0 inches,*[2] *Alabama, 1982*

Forest survey unit	5.0–9.9		10.0–14.9		≥15.0	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons					
Southwest-South	13.9	55.4	8.7	51.2	7.2	60.8
Southwest-North	26.6	93.9	26.9	55.4	15.6	118.9
Southeast	53.6	153.8	52.5	130.3	43.6	147.4
West Central	16.2	107.2	12.6	71.5	6.1	100.8
North Central	25.7	138.7	18.8	123.0	11.3	139.7
North	11.6	75.8	7.2	73.8	5.6	123.0
State	147.6	624.8	126.7	505.2	89.4	690.6

[1]Includes sound portion only.
[2]Totals may not add due to rounding.

Table 12.—*Green weight of total woody biomass by softwood species groups,*[1] *Alabama, 1982*

Forest survey unit	Longleaf	Slash	Loblolly	Shortleaf	Other	Total
	Hundred thousand tons					
Southwest-South	322.2	368.2	152.7	16.6	36.6	896.3
Southwest-North	38.1	49.5	725.4	206.0	90.7	1,109.5
Southeast	88.4	84.8	1,002.1	286.2	58.5	1,520.0
West Central	50.1	5.5	683.4	161.6	83.4	984.1
North Central	87.9	4.0	793.5	224.9	189.3	1,299.5
North	0.0	0.0	178.1	62.2	112.6	352.9
State	586.7	512.0	3,535.2	957.4	571.1	6,162.3

[1]Totals may not add due to rounding.

Table 13.—*Green weight of total woody biomass by hardwood species groups,*[1] *Alabama, 1982*

Forest survey unit	Oaks	Sweetgum	Yellow Poplar	Hickories	Gums	Other	Total
	Hundred thousand tons						
Southwest-South	264.5	62.4	28.5	17.3	171.3	253.5	797.5
Southwest-North	594.7	283.7	47.5	94.9	90.0	421.9	1,532.7
Southeast	804.2	440.9	112.6	140.1	148.9	496.2	2,143.0
West Central	691.8	262.0	62.7	127.4	113.2	328.2	1,585.2
North Central	975.3	170.0	126.7	244.3	39.2	316.9	1,872.3
North	690.7	111.1	57.4	219.6	40.4	300.4	1,419.5
State	4,021.2	1,330.2	435.3	843.5	603.0	2,117.0	9,350.2

[1]Totals may not add due to rounding.

Table 14.—*Area of timberland by basal area class,[1] Alabama, 1982*

Forest survey unit	Basal area class[2] (midpoint)							
	10	30	50	70	90	110	130	≥140
	Thousand acres							
Southwest-South	408.6	419.1	543.5	476.9	365.2	255.8	200.6	188.6
Southwest-North	388.7	395.5	331.6	558.2	619.5	466.2	330.0	292.8
Southeast	586.3	573.7	838.3	954.0	1,081.9	649.4	397.5	334.7
West Central	338.9	240.1	427.1	547.3	539.8	490.4	369.7	318.7
North Central	507.1	376.6	599.3	869.2	856.9	618.5	394.4	320.7
North	127.7	92.8	263.4	478.8	499.2	365.0	187.3	173.4
State	2,357.3	2,097.8	3,003.3	3,884.5	3,962.4	2,845.4	1,879.5	1,628.8

[1]Totals may not add due to rounding.
[2]Basal area in square feet per acre.

Table 15.—*Green weight of total woody biomass by basal area class,[1] Alabama, 1982*

Forest survey unit	Basal area class[2] (midpoint)							
	10	30	50	70	90	110	130	≥140
	Hundred thousand tons							
Southwest-South	23.0	98.9	213.8	284.9	283.9	250.4	228.7	309.9
Southwest-North	13.5	92.1	144.9	349.7	573.6	523.3	468.8	476.4
Southeast	28.5	138.5	340.6	570.0	888.2	668.9	510.9	517.3
West Central	10.5	58.4	177.0	340.4	453.7	519.2	489.3	520.7
North Central	25.2	87.6	242.8	517.4	679.5	624.3	482.9	511.9
North	5.1	21.7	111.0	300.8	412.4	391.4	239.6	290.3
State	105.8	497.2	1,230.1	2,363.2	3,291.3	2,977.5	2,420.2	2,626.5

[1] Totals may not add due to rounding.
[2] Basal area in square feet per acre.

Table 16.—*Green weight of merchantable woody biomass by basal area class,[1] Alabama, 1982*

Forest survey unit	Basal area class[2] (midpoint)							
	10	30	50	70	90	110	130	≥140
	Hundred thousand tons							
Southwest-South	10.3	51.9	107.5	147.1	151.6	143.2	127.2	173.8
Southwest-North	3.8	38.6	62.4	185.0	314.4	287.5	263.1	258.0
Southeast	9.8	51.7	152.7	274.7	446.1	339.5	276.9	284.2
West Central	3.9	22.7	79.9	167.3	226.8	279.5	280.8	302.8
North Central	9.6	38.1	99.1	228.1	316.8	332.3	262.0	303.2
North	0.8	5.7	47.9	129.2	181.0	186.6	120.1	152.4
State	38.2	208.7	549.5	1,131.4	1,636.7	1,568.6	1,330.1	1,474.4

[1] Totals may not add due to rounding.
[2] Basal area in square feet per acre.

Table 17.—*Green weight of residual woody biomass by basal area class,[1] Alabama, 1982*

Forest survey unit	Basal area class[2] (midpoint)							
	10	30	50	70	90	110	130	≥140
	Hundred thousand tons							
Southwest-South	12.7	47.0	106.2	137.7	132.3	107.2	101.5	136.1
Southwest-North	9.6	53.5	82.5	164.7	259.2	235.8	205.7	218.3
Southeast	18.8	86.8	187.8	295.3	442.1	329.4	234.0	233.1
West Central	6.7	35.7	97.1	173.1	226.9	239.7	208.5	217.9
North Central	15.6	49.4	143.7	289.4	362.7	292.1	220.9	208.8
North	4.3	16.0	63.1	171.7	231.5	204.9	119.5	137.9
State	67.7	288.4	680.4	1,231.9	1,654.7	1,409.1	1,090.1	1,152.1

[1] Totals may not add due to rounding.
[2] Basal area in square feet per acre.

Table 18.—*Green weight of rough and rotten[1] woody biomass by basal area class,[2] Alabama, 1982*

Forest survey unit	Basal area class[3] (midpoint)							
	10	30	50	70	90	110	130	≥140
	Hundred thousand tons							
Southwest-South	1.7	9.5	18.9	37.6	35.7	20.7	32.9	40.2
Southwest-North	1.9	14.3	19.0	45.1	68.7	71.3	59.4	57.9
Southeast	5.0	33.0	60.7	87.9	140.4	105.3	78.5	70.4
West Central	1.2	7.9	30.8	47.2	61.3	60.4	49.3	56.5
North Central	2.4	10.4	47.4	96.3	111.5	83.8	55.1	50.2
North	1.4	5.7	19.0	46.1	72.9	66.9	39.1	45.8
State	13.6	80.8	195.8	360.2	490.5	408.4	314.3	321.0

[1] Includes sound portion only.
[2] Totals may not add due to rounding.
[3] Basal area in square feet per acre.

Table 19.—*Green weight of sapling woody biomass by basal area class,[1] Alabama, 1982*

Forest survey unit	Basal area class[2] (midpoint)							
	10	30	50	70	90	110	130	≥140
	Hundred thousand tons							
Southwest-South	7.4	23.2	55.4	56.4	50.1	39.1	29.4	33.7
Southwest-North	9.3	35.3	74.2	111.2	150.6	107.1	60.2	61.7
Southeast	6.4	25.8	38.9	59.6	72.4	61.8	52.4	66.2
West Central	3.8	17.9	35.6	60.6	80.6	70.2	60.3	56.6
North Central	9.7	24.4	60.1	108.3	128.2	91.9	72.6	69.7
North	2.4	7.5	22.9	60.7	71.3	47.0	25.8	26.8
State	39.0	134.1	287.3	456.8	553.2	417.1	300.7	314.7

[1] Totals may not add due to rounding.
[2] Basal area in square feet per acre.

Table 20.—*Green weight of total woody biomass by ownership,[1] Alabama, 1982*

Forest survey unit	Public		Forest industry		Farmer		Miscellaneous private	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons							
Southwest-South	53.9	14.6	291.4	229.3	149.9	153.0	401.1	400.6
Southwest-North	18.1	24.9	376.1	405.5	289.7	467.3	425.6	635.0
Southeast	60.1	73.8	311.2	268.7	518.1	938.7	630.6	861.8
West Central	100.2	67.6	289.3	329.6	164.2	415.3	430.4	772.7
North Central	156.3	231.7	199.0	239.7	220.4	351.9	723.8	1,049.0
North	33.2	170.0	32.4	99.9	148.7	628.9	138.6	520.7
State	421.7	582.6	1,499.4	1,572.6	1,491.1	2,955.2	2,750.2	4,239.7

[1] Totals may not add due to rounding.

Table 21.—*Green weight of merchantable woody biomass by ownership,[1] Alabama, 1982*

Forest survey unit	Public		Forest industry		Farmer		Miscellaneous private	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons							
Southwest-South	41.2	5.4	201.0	92.2	104.4	56.2	269.9	142.0
Southwest-North	14.5	9.7	262.6	162.1	206.3	194.4	303.3	259.3
Southeast	44.2	31.2	188.5	100.4	352.8	381.3	416.8	320.5
West Central	75.0	25.0	211.7	138.9	120.4	176.5	298.5	317.7
North Central	115.0	84.1	132.5	73.4	153.4	138.3	500.9	391.5
North	23.3	69.8	19.0	42.0	101.6	265.6	93.7	208.6
State	313.1	225.3	1,015.3	609.0	1,038.9	1,212.8	1,883.1	1,639.6

[1] Totals may not add due to rounding.

Table 22.—*Green weight of residual woody biomass by ownership,[1] Alabama, 1982*

Forest survey unit	Public		Forest industry		Farmer		Miscellaneous private	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons							
Southwest-South	12.6	9.2	90.3	137.1	45.5	96.8	131.2	258.5
Southwest-North	3.6	15.2	113.5	243.3	83.4	272.4	122.3	375.7
Southeast	15.9	42.6	122.7	168.3	165.3	557.4	213.8	541.3
West Central	25.9	42.5	77.7	190.7	43.8	238.8	131.9	454.9
North Central	41.3	147.5	66.4	166.3	67.0	213.6	222.9	657.5
North	9.9	100.2	13.4	57.9	47.1	363.3	44.9	312.1
State	109.2	357.3	484.0	963.7	452.2	1,742.4	867.0	2,600.1

[1] Totals may not add due to rounding.

Table 23.—*Green weight of rough and rotten[1] woody biomass by ownership,[2] Alabama, 1982*

Forest survey unit	Public		Forest industry		Farmer		Miscellaneous private	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons							
Southwest-South	2.0	4.6	9.1	40.6	5.6	35.1	13.1	87.5
Southwest-North	0.0	7.4	15.6	69.4	25.7	86.5	27.9	104.9
Southeast	4.0	13.5	39.1	50.6	48.9	187.6	57.7	179.8
West Central	1.9	9.6	9.6	53.0	6.1	74.8	17.4	142.1
North Central	7.1	49.4	6.4	49.1	9.3	74.1	33.1	228.7
North	1.3	29.1	3.0	18.0	12.7	118.9	7.5	106.6
State	16.3	113.5	82.8	280.6	108.3	577.2	156.5	849.7

[1] Includes sound portion only.
[2] Totals may not add due to rounding.

Table 24.—*Green weight of sapling[1] woody biomass by ownership,[2] Alabama, 1982*

Forest survey unit	Public		Forest industry		Farmer		Miscellaneous private	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons							
Southwest-South	1.5	2.1	34.8	51.2	16.0	35.0	54.9	99.1
Southwest-North	1.0	1.5	40.2	81.8	14.1	88.3	29.5	127.3
Southeast	2.1	14.7	38.4	64.2	40.9	182.6	65.7	201.1
West Central	7.1	18.3	21.1	59.8	13.2	72.1	44.8	148.9
North Central	10.7	52.1	29.9	77.5	21.9	66.3	79.2	227.3
North	3.4	28.5	6.2	17.0	12.4	98.6	16.8	81.7
State	25.9	117.2	170.6	351.6	118.6	543.0	290.8	885.4

[1] Includes all trees 1.0 to 4.9 inches in diameter.
[2] Totals may not add due to rounding.

Table 25.—*Green weight of total woody biomass by forest type,[1] Alabama, 1982*

Forest survey unit	Longleaf-slash		Loblolly-shortleaf		Oak-pine		Oak-hickory		Oak-gum-cypress[2]	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons									
Southwest-South	528.0	87.7	95.3	28.6	184.9	163.7	35.0	145.3	53.1	371.8
Southwest-North	52.5	12.7	710.7	220.4	223.2	251.8	72.4	506.9	50.8	541.0
Southeast	118.9	16.6	926.6	239.7	325.5	412.6	127.9	941.5	21.0	532.6
West Central	35.1	8.4	649.2	179.3	212.9	292.3	67.6	611.0	19.3	494.1
North Central	56.8	10.9	842.3	260.9	278.4	409.1	119.2	1,093.0	2.8	98.3
North	0.0	0.0	195.3	74.4	100.6	165.0	49.2	1,037.5	7.9	142.6
State	791.3	136.3	3,419.4	1,003.3	1,325.5	1,694.5	471.3	4,335.2	154.9	2,180.4

[1] Totals may not add due to rounding.
[2] Includes elm-ash-cottonwood type.

Table 26.—*Green weight of merchantable woody biomass by forest type,[1] Alabama, 1982*

Forest survey unit	Longleaf-slash		Loblolly-shortleaf		Oak-pine		Oak-hickory		Oak-gum-cypress[2]	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons									
Southwest-South	358.9	17.8	56.2	7.1	137.4	54.5	24.1	50.2	40.1	166.2
Southwest-North	32.2	4.1	497.6	75.1	166.7	92.3	51.6	211.4	38.6	243.2
Southeast	82.2	4.0	594.4	73.6	221.7	150.7	88.4	368.6	15.5	236.3
West Central	27.5	1.3	459.4	58.3	155.6	102.7	48.6	260.7	14.5	235.2
North Central	38.6	1.8	587.2	74.5	192.5	131.6	81.8	442.5	1.7	37.0
North	0.0	0.0	126.4	20.9	72.6	63.0	32.0	438.0	6.6	64.1
State	539.4	29.0	2,321.2	309.5	946.5	594.8	326.5	1,771.4	117.0	982.0

[1] Totals may not add due to rounding.
[2] Includes elm-ash-cottonwood type.

Table 27.—*Green weight of residual woody biomass by forest type,[1] Alabama, 1982*

Forest survey unit	Longleaf-slash		Loblolly-shortleaf		Oak-pine		Oak-hickory		Oak-gum-cypress[2]	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons									
Southwest-South	169.1	69.9	39.0	21.5	47.5	109.2	10.9	95.1	13.0	205.6
Southwest-North	20.3	8.6	213.1	145.3	56.5	159.5	20.7	295.6	12.1	297.7
Southeast	36.7	12.6	332.2	166.1	103.8	261.9	39.6	572.8	5.5	296.2
West Central	7.6	7.1	189.9	121.1	57.3	189.6	19.0	350.3	4.8	259.0
North Central	18.2	9.1	255.1	186.4	85.9	277.6	37.3	650.5	1.1	61.3
North	0.0	0.0	68.9	53.4	28.0	102.0	17.2	599.5	1.2	78.6
State	251.9	107.3	1,098.2	693.8	379.0	1,099.8	144.7	2,563.8	37.7	1,198.4

[1] Totals may not add due to rounding.
[2] Includes elm-ash-cottonwood type.

Table 28.—*Green weight of rough and rotten[1] woody biomas by forest type,[2] Alabama, 1982*

Forest survey unit	Longleaf-slash		Loblolly-shortleaf		Oak-pine		Oak-hickory		Oak-gum-cypress[3]	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons									
Southwest-South	14.1	16.4	6.1	5.2	6.3	34.7	2.3	37.6	0.9	73.4
Southwest-North	1.9	3.0	50.9	33.5	9.1	41.7	5.3	86.3	2.0	103.7
Southeast	14.6	3.4	93.6	40.5	30.2	81.9	9.4	197.5	1.9	108.1
West Central	0.0	3.7	21.4	26.4	9.8	61.2	3.4	98.4	0.4	89.9
North Central	1.1	5.1	33.6	57.9	14.7	99.9	5.6	213.8	0.7	24.6
North	0.0	0.0	14.4	21.7	4.7	32.8	5.3	192.3	0.0	25.9
State	31.7	31.6	220.0	185.2	74.8	352.2	31.3	825.9	5.9	425.6

[1] Includes sound portion only.
[2] Totals may not add due to rounding.
[3] Includes elm-ash-cottonwood type.

Table 29.—*Green weight of sapling[1] woody biomass by forest type,[2] Alabama, 1982*

Forest survey unit	Longleaf-slash		Loblolly-shortleaf		Oak-pine		Oak-hickory		Oak-gum-cypress[3]	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons									
Southwest-South	70.1	44.9	18.6	12.8	11.6	48.4	3.3	31.8	3.7	49.6
Southwest-North	11.4	3.2	55.7	78.0	12.7	69.7	4.5	92.5	0.5	55.4
Southeast	4.2	7.8	107.3	90.0	24.8	108.4	10.7	191.9	0.1	64.4
West Central	2.1	2.6	65.8	64.3	13.4	75.6	4.9	114.8	0.1	41.8
North Central	8.0	3.3	90.7	93.6	29.2	109.8	13.8	202.6	0.1	14.1
North	0.0	0.0	25.1	20.4	8.5	35.5	5.2	151.7	0.0	18.2
State	95.8	61.8	363.2	359.1	100.2	447.4	42.4	785.3	4.5	243.5

[1] Includes all trees 1.0 to 4.9 inches in diameter.
[2] Totals may not add due to rounding.
[3] Includes elm-ash-cottonwood type.

Table 30.—*Total woody biomass by species component and group, Alabama, 1982*

Group	All species	Softwood	Hardwood
	Green tons per acre		
Ownership			
Public	86	36	50
Forest industry	81	40	41
Farmer	68	23	45
Miscellaneous private	69	27	42
Forest type			
Longleaf-slash	63	53	9
Loblolly-shortleaf	75	58	17
Oak-pine	66	29	37
Oak-hickory	66	6	60
Oak-gum-cypress[1]	95	6	89
Physiographic class			
Pine	67	32	35
Upland hardwood	86	4	82
Bottomland hardwood	95	9	86
Stand origin			
Natural regeneration	76	28	48
Artificial regeneration	44	34	10

[1]Includes elm-ash-cottonwood type.

Table 31.—*Area of timberland harvested by type of harvest,[1] Alabama, 1982*

Forest survey unit	Clearcut	Partial[2] cut	Diameter-limit cut	Salvage cut
	Thousand acres			
Southwest-South	204.3	380.1	95.7	95.7
Southwest-North	419.3	607.4	146.3	12.0
Southeast	629.3	828.3	285.2	65.4
West Central	413.9	424.1	51.4	11.8
North Central	662.5	468.7	108.1	28.1
North	153.1	150.2	18.3	12.4
State	2,482.2	2,858.8	704.9	225.4

[1]Totals may not add due to rounding.

[2]Includes seed tree, strip cut, shelterwood, group selection, and single tree selection.

Table 32.—*Green weight of woody biomass on clearcut, pine upland,[1] Alabama, 1982*

Forest survey unit	Total green weight[2]		Merchantable green weight[3]		Residual green weight[4]	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons					
Southwest-South	108.2	70.7	53.0	24.5	55.2	44.2
Southwest-North	259.6	199.7	162.0	74.9	97.6	121.9
Southeast	296.4	283.6	150.3	85.1	146.1	205.3
West Central	228.8	188.8	109.5	64.0	119.3	124.8
North Central	345.5	257.4	187.0	82.6	158.6	172.8
North	47.7	74.4	21.8	23.3	26.0	51.2
State	1,286.2	1,074.6	683.6	354.4	602.8	720.2

[1]Totals may not add due to rounding.

[2]Includes all trees prior to cutting operation.

[3]Includes only merchantable sections removed during cutting operation.

[4]Includes residual of removed trees and total green weight of all trees left standing or knocked down after cutting operation.

Table 33.—*Green weight of woody biomass on partial cut,[1] pine upland,[2] Alabama, 1982*

Forest survey unit	Total green weight[3]		Merchantable green weight[4]		Residual green weight[5]	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons					
Southwest-South	190.2	102.2	47.9	11.6	142.2	90.7
Southwest-North	385.9	292.3	111.0	51.6	274.9	240.8
Southeast	500.8	407.1	155.9	59.9	344.9	347.2
West Central	236.1	203.6	80.7	28.3	155.9	175.3
North Central	256.8	239.3	91.4	27.1	165.4	212.2
North	51.7	122.3	15.1	19.5	36.4	102.8
State	1,621.5	1,366.8	502.0	198.0	1,119.8	1,169.0

[1]Includes seed tree, strip cut, shelterwood, group selection, and single tree selection.
[2]Totals may not add due to rounding.
[3]Includes all trees prior to cutting operation.
[4]Includes only merchantable sections removed during cutting operation.
[5]Includes residual of removed trees and total green weight of all trees left standing or knocked down after cutting operation.

Table 34.—*Green weight of woody biomass on diameter-limit cut, pine upland,[1] Alabama, 1982*

Forest survey unit	Total green weight[2]		Merchantable green weight[3]		Residual green weight[4]	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons					
Southwest-South	85.3	36.7	27.8	3.0	57.5	33.7
Southwest-North	103.3	89.3	32.7	22.9	70.6	66.4
Southeast	137.7	135.3	54.4	18.6	83.3	115.2
West Central	26.9	33.3	11.1	5.4	15.8	29.9
North Central	45.6	58.7	17.1	13.8	28.5	44.8
North	6.5	14.8	0.0	4.7	6.5	10.1
State	405.3	368.1	143.1	68.4	262.2	300.1

[1]Totals may not add due to rounding.
[2]Includes all trees prior to cutting operation.
[3]Includes only merchantable sections removed during cutting operation.
[4]Includes residual of removed trees and total green weight of all trees left standing or knocked down after cutting operation.

Table 35.—*Green weight of woody biomass on salvage cut, pine upland,[1] Alabama, 1982*

Forest survey unit	Total green weight[2]		Merchantable green weight[3]		Residual green weight[4]	
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
	Hundred thousand tons					
Southwest-South	48.4	43.2	12.8	2.7	35.7	40.5
Southwest-North	12.4	3.2	2.3	0.0	10.5	3.2
Southeast	50.6	21.5	12.4	0.5	38.2	21.0
West Central	12.2	0.9	0.5	0.0	11.7	0.9
North Central	20.6	4.4	4.7	0.0	16.0	4.4
North	6.3	11.2	2.1	3.0	4.2	8.2
State	150.8	84.4	34.7	6.2	116.1	78.2

[1]Totals may not add due to rounding.
[2]Includes all trees prior to cutting operation.
[3]Includes only merchantable sections removed during cutting operation.
[4]Includes residual of removed trees and total green weight of all trees left standing or knocked down after cutting operation.

Table 36.—*Woody biomass remaining after clearcut operation on pine upland, by standing live and downed biomass, Alabama, 1982*[1]

Forest survey unit	Downed biomass			
	Softwood	Hardwood	Softwood	Hardwood
	- Hundred thousand tons -		*--- Green tons per acre ---*	
Southwest-South	46.4	31.0	23	15
Southwest-North	78.8	74.3	19	18
Southeast	132.1	175.5	21	28
West Central	100.3	89.9	24	22
North Central	132.5	129.5	20	20
North	23.7	39.6	16	26
State	513.7	539.8	21	21

	Standing live biomass			
	Softwood	Hardwood	Softwood	Hardwood
	- Hundred thousand tons -		--- Green tons per acre ---	
Southwest-South	8.8	13.2	4	6
Southwest-North	18.8	47.6	4	11
Southeast	13.9	29.8	2	5
West Central	19.0	34.9	5	8
North Central	26.1	43.3	4	7
North	2.4	11.5	2	8
State	89.1	180.4	4	6

[1]Totals may not add due to rounding.

Table 37.—*Green weight of woody biomass by county and species component,*[1] *Alabama, 1982*

County	All species	Softwood			Hardwood		
		Total green weight	Merchantable green weight	Residual green weight	Total green weight	Merchantable green weight	Residual green weight
	Hundred thousand tons						
Autauga	148.7	82.0	57.5	24.5	66.7	21.0	45.7
Baldwin	439.3	234.7	165.6	69.1	204.5	83.2	121.4
Barbour	272.1	135.4	95.3	40.1	136.8	59.9	76.8
Bibb	226.0	112.0	78.5	33.5	114.0	42.1	71.9
Blount	151.3	46.5	33.3	13.2	104.8	46.0	58.8
Bullock	165.7	74.9	49.0	25.9	90.8	34.6	56.2
Butler	257.1	142.5	91.8	50.7	114.6	44.6	70.0
Calhoun	195.2	72.8	54.4	18.4	122.4	46.2	76.2
Chambers	189.9	103.8	69.7	34.1	86.1	34.9	51.2
Cherokee	139.6	49.7	27.7	22.0	89.9	32.5	57.3
Chilton	197.2	75.7	50.1	25.6	121.5	44.6	76.9
Choctaw	424.3	196.1	139.1	57.0	228.3	91.4	136.9
Clarke	592.3	241.6	181.2	60.4	350.7	150.2	200.5
Clay	184.3	63.1	40.6	22.5	121.2	38.8	82.4
Cleburne	237.6	96.7	68.3	28.4	140.9	46.9	93.9
Coffee	164.9	56.9	32.9	24.0	108.1	40.4	67.6
Colbert	138.5	24.1	15.1	9.0	114.4	47.6	66.8
Conecuh	273.4	98.7	58.6	40.1	174.7	67.5	107.2
Coosa	207.7	77.8	49.0	28.8	129.8	46.9	83.0
Covington	248.7	138.6	91.3	47.2	110.1	38.0	72.1
Crenshaw	208.8	81.0	51.2	29.8	127.9	52.7	75.2
Cullman	203.5	92.9	67.2	25.7	110.5	50.4	60.2
Dale	152.6	53.7	38.4	15.4	98.9	38.5	60.4
Dallas	223.3	86.4	53.9	32.5	136.9	49.4	87.5
De Kalb	209.1	65.7	49.0	16.7	143.4	49.2	94.2
Elmore	166.6	45.5	25.5	20.0	121.1	44.8	76.3
Escambia	338.4	211.8	149.4	62.4	126.6	47.4	79.2
Etowah	145.1	55.6	40.3	15.3	89.5	33.4	56.1

Table 37.—*Green weight of woody biomass by county and species component,[1] Alabama, 1982—Continued*

County	All species	Softwood			Hardwood		
		Total green weight	Merchantable green weight	Residual green weight	Total green weight	Merchantable green weight	Residual green weight
	Hundred thousand tons						
Fayette	257.7	85.7	61.6	24.1	172.0	81.5	90.5
Franklin	185.5	45.3	27.1	18.2	140.0	58.4	81.6
Geneva	74.2	21.5	16.3	5.1	52.7	19.2	33.5
Greene	223.5	63.2	48.1	15.1	160.3	67.8	92.5
Hale	198.4	71.5	53.0	18.4	127.0	52.7	74.2
Henry	125.9	46.8	32.9	13.9	79.1	27.5	51.6
Houston	75.9	30.8	18.7	12.1	45.1	18.8	26.3
Jackson	327.3	30.7	19.6	11.1	296.6	121.3	175.3
Jefferson	346.7	175.2	125.6	49.6	171.6	59.6	112.0
Lamar	223.0	57.1	38.0	19.0	165.9	69.5	96.4
Lauderdale	130.7	25.4	15.4	10.1	105.3	42.4	62.9
Lawrence	155.3	37.1	24.0	13.1	118.3	52.0	66.3
Lee	143.1	70.6	40.2	30.4	72.6	24.8	47.7
Limestone	120.5	8.1	6.6	1.5	112.4	52.3	60.2
Lowndes	184.2	68.2	44.3	23.9	116.0	49.9	66.0
Macon	175.5	49.6	33.2	16.4	125.9	49.1	76.8
Madison	182.4	26.7	16.4	10.4	155.7	61.4	94.2
Marengo	319.1	140.6	104.6	36.0	178.5	77.6	100.9
Marion	226.7	74.2	52.4	21.7	152.5	55.7	96.9
Marshall	178.9	53.4	37.7	15.7	125.5	52.4	73.0
Mobile	249.0	125.7	85.1	40.7	123.3	39.2	84.1
Monroe	413.8	172.6	119.6	53.0	241.2	92.4	148.8
Montgomery	173.0	70.5	48.4	22.2	102.4	43.6	58.9
Morgan	144.5	36.5	26.9	9.6	108.0	49.0	59.0
Perry	223.9	105.6	73.3	32.3	118.4	48.8	69.6
Pickens	390.0	166.3	119.1	47.2	223.6	89.4	134.2
Pike	132.2	45.6	31.5	14.1	86.7	34.3	52.3
Randolph	137.0	48.7	32.1	16.6	88.3	32.5	55.8
Russell	190.5	97.2	70.2	27.0	93.4	39.4	54.0
St. Clair	182.7	70.9	46.3	24.6	111.8	41.4	70.4
Shelby	247.7	114.0	80.1	33.9	133.7	40.7	93.0
Sumter	280.0	100.1	77.3	22.8	179.9	73.6	106.3
Talladega	182.8	78.0	53.3	24.7	104.8	33.0	71.8
Tallapoosa	241.4	81.6	51.5	30.1	159.8	61.1	98.7
Tuscaloosa	600.0	248.6	181.5	67.1	351.5	150.7	200.8
Walker	324.2	130.3	94.3	35.9	193.9	73.3	120.6
Washington	418.1	185.4	125.4	60.1	232.6	88.1	144.6
Wilcox	339.4	159.9	106.4	53.5	179.5	73.4	106.0
Winston	286.5	127.3	89.4	37.9	159.2	65.8	93.4
State	15,512.3	6,162.4	4,250.6	1,911.6	9,350.1	3,686.7	5,663.5

[1]Totals may not add due to rounding.

Table 38.—*Sampling errors[1] for green woody biomass components by county, Alabama, 1982*

County	All species			Softwood			Hardwood		
	Total green weight	Merchantable green weight	Residual green weight	Total green weight	Merchantable green weight	Residual green weight	Total green weight	Merchantable green weight	Residual green weight
	Percent								
Autauga	10.0	12.5	9.9	13.6	14.7	14.8	19.3	29.3	16.4
Baldwin	6.9	7.9	10.0	9.1	10.1	9.3	13.4	16.3	15.5
Barbour	6.8	8.9	6.5	12.0	12.9	13.6	11.3	14.6	10.2
Bibb	8.9	12.2	7.8	15.0	17.3	13.0	11.4	14.6	11.1
Blount	11.7	14.3	11.8	24.3	27.3	20.3	16.2	19.0	15.3
Bullock	9.0	10.4	11.2	17.5	18.5	19.4	14.9	15.9	16.2
Butler	8.0	10.6	7.2	11.9	13.7	12.6	12.9	15.4	12.3

Table 38.—*Sampling errors*[1] *for green woody biomass components by county, Alabama, 1982—Continued*

County	All species			Softwood			Hardwood		
	Total green weight	Merchantable green weight	Residual green weight	Total green weight	Merchantable green weight	Residual green weight	Total green weight	Merchantable green weight	Residual green weight
	Percent								
Calhoun	8.0	11.8	7.2	20.7	20.9	22.0	10.9	16.3	9.9
Chambers	6.9	9.7	6.3	13.0	14.5	13.8	14.3	18.8	12.7
Cherokee	9.9	13.9	9.4	17.9	21.1	17.8	16.4	24.5	13.9
Chilton	7.7	10.4	6.5	13.9	15.1	15.7	10.0	14.7	8.5
Choctaw	7.0	8.2	7.6	11.5	12.1	12.8	11.1	14.6	10.1
Clarke	5.4	6.3	5.5	8.9	9.4	10.1	8.1	10.5	7.1
Clay	7.1	9.4	7.1	15.1	16.5	15.5	10.0	13.7	9.5
Cleburne	7.2	8.3	7.5	12.4	12.8	14.3	10.4	14.1	9.9
Coffee	9.8	13.5	8.3	17.4	18.0	22.7	14.6	21.4	11.7
Colbert	9.2	10.7	9.7	21.9	21.4	25.9	11.9	13.9	11.9
Conecuh	9.2	11.7	8.8	13.8	15.8	15.6	13.0	17.1	11.8
Coosa	9.3	11.3	9.2	14.6	17.3	13.8	14.8	18.5	13.4
Covington	7.9	10.5	8.0	12.7	14.4	12.3	13.6	20.7	12.4
Crenshaw	10.8	14.6	9.2	20.7	23.5	20.7	13.3	16.9	12.1
Cullman	9.6	12.6	8.3	21.1	22.9	19.7	14.3	18.3	12.5
Dale	10.3	12.7	10.0	20.2	21.5	19.9	11.9	14.5	11.8
Dallas	8.0	11.3	7.2	16.7	19.6	15.5	10.7	14.8	9.7
De Kalb	9.1	10.7	9.8	17.7	18.8	18.1	13.7	18.4	12.2
Elmore	8.7	12.4	8.2	16.8	20.4	17.9	12.9	17.9	11.7
Escambia	8.0	9.8	7.7	10.3	11.8	10.3	15.9	21.8	13.8
Etowah	9.3	14.6	8.5	23.0	25.7	21.4	13.0	18.1	12.4
Fayette	8.2	10.5	7.2	20.7	21.6	20.5	11.2	13.6	9.9
Franklin	9.6	12.0	8.7	18.1	20.0	20.1	12.2	14.9	11.1
Geneva	10.9	16.8	11.2	32.8	35.7	28.3	16.4	22.9	15.1
Greene	9.5	11.2	9.3	20.8	21.5	21.7	11.5	13.9	10.7
Hale	9.1	11.4	9.6	17.7	19.5	18.5	12.3	14.6	12.6
Henry	10.5	11.7	11.7	20.1	20.5	21.1	16.0	19.6	15.5
Houston	15.0	18.1	14.7	28.5	31.9	30.8	20.4	24.1	19.0
Jackson	5.7	7.5	5.4	22.6	25.6	21.9	6.3	8.5	5.9
Jefferson	7.2	10.3	5.9	13.9	15.5	12.9	9.6	12.3	8.9
Lamar	8.0	10.7	8.0	22.1	22.7	24.9	11.5	15.0	10.8
Lauderdale	8.8	11.6	10.0	39.6	44.1	39.7	12.8	14.2	13.5
Lawrence	9.6	12.4	8.9	23.6	27.8	20.7	13.1	16.3	11.7
Lee	8.9	12.0	9.3	14.9	17.4	15.6	15.9	20.9	15.8
Limestone	12.8	13.7	13.0	74.5	73.6	78.8	12.1	12.9	12.7
Lowndes	9.6	13.0	8.3	20.6	23.4	19.6	12.8	16.6	11.7
Macon	11.1	14.4	10.3	21.3	24.2	21.3	15.0	20.8	13.3
Madison	8.6	12.8	7.7	28.1	34.9	30.1	10.1	14.8	9.5
Marengo	7.0	8.4	7.8	13.1	13.9	13.1	12.8	15.6	11.9
Marion	8.6	12.3	7.8	23.2	24.8	21.7	10.9	14.3	10.1
Marshall	9.5	13.3	8.3	22.7	25.0	23.0	13.4	18.5	11.2
Mobile	8.8	10.8	8.7	11.2	12.6	11.7	13.7	20.2	12.5
Monroe	6.4	7.3	7.0	10.3	11.0	12.8	9.6	11.1	9.5
Montgomery	10.8	12.7	11.5	21.4	21.5	22.9	18.2	22.0	17.5
Morgan	8.9	12.8	7.0	25.1	25.8	25.3	11.6	16.7	9.3
Perry	9.0	11.9	8.3	15.3	18.0	13.4	14.4	17.7	13.7
Pickens	6.6	8.2	6.7	12.5	13.5	12.1	10.8	14.5	9.4
Pike	10.4	14.2	9.1	20.9	22.0	22.9	12.7	18.3	11.8
Randolph	9.6	12.4	9.3	20.7	21.6	21.7	12.2	14.9	12.2
Russell	12.2	13.5	12.7	17.7	18.0	19.8	19.5	28.0	16.2
St. Clair	8.7	10.7	8.5	15.9	17.7	15.2	11.2	13.4	10.9
Shelby	7.0	9.9	6.8	13.6	14.9	13.7	10.2	14.9	9.9
Sumter	8.2	10.5	8.3	18.4	19.2	18.9	11.7	15.5	10.6
Talladega	7.8	11.5	7.4	15.8	16.6	17.0	10.0	16.7	9.7
Tallapoosa	7.5	9.5	7.8	15.5	17.8	16.5	10.3	13.5	10.0
Tuscaloosa	5.1	6.3	5.3	10.3	10.8	10.9	8.7	11.1	7.7
Walker	7.4	9.0	7.4	14.1	15.1	13.5	9.1	11.1	9.1
Washington	6.3	7.7	9.0	9.2	10.2	10.6	11.3	13.6	13.2
Wilcox	8.2	9.8	8.3	12.5	13.7	15.4	13.5	16.4	12.3
Winston	6.7	9.4	6.0	14.5	16.0	14.3	10.8	14.7	9.6
State	1.2	1.4	1.2	2.0	2.2	2.1	1.6	2.1	1.5

[1]By random-sampling formula.

Table 39.—*Sampling errors*[1] *for green woody biomass components, by unit, Alabama, 1982*

Forest survey unit	All species			Softwood			Hardwood		
	Total green weight	Merchantable green weight	Residual green weight	Total green weight	Merchantable green weight	Residual green weight	Total green weight	Merchantable green weight	Residual green weight
	Percent								
Southwest-South	3.4	4.2	4.2	4.7	5.3	4.8	6.1	8.0	6.6
Southwest-North	2.7	3.2	2.8	4.6	4.9	5.3	4.1	5.3	3.8
Southeast	2.1	2.7	2.0	3.8	4.2	4.1	3.1	4.1	2.9
West Central	2.6	3.3	2.5	5.3	5.8	5.3	3.8	4.9	3.5
North Central	2.2	3.0	2.1	4.4	4.9	4.2	3.1	4.2	2.8
North	3.0	3.8	2.9	8.2	9.0	8.2	3.7	4.7	3.5

[1]By random-sampling formula.

Rosson, J. F., Jr. and Thomas, C. E. The woody biomass resource of Alabama. Res. Pap. SO-228. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1986. 31 p.

Presents findings and analysis of woody biomass based on the fifth forest survey of Alabama (1982). The green weights by component—total, merchantable, residual, sapling, and rough and rotten—are presented by various categories such as ownership, forest type, physiographic class, size class, basal area, species, and age. After-harvest residual is also presented and discussed.

Additional keywords: biomass, green weight, merchantable weight, residual weight, harvesting, clearcut, basal area, forest ecosystem.

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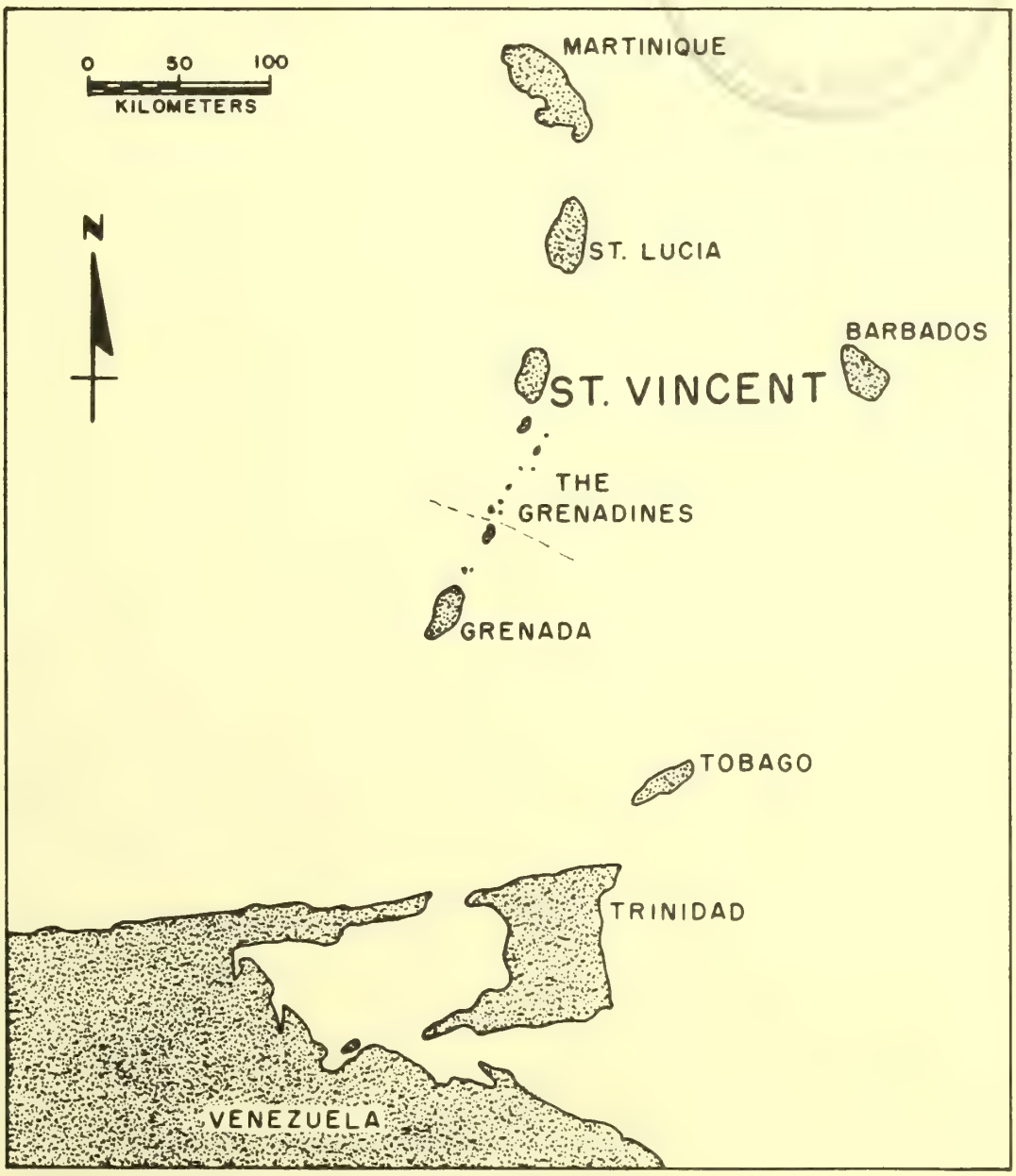
The Forest Resources of St. Vincent, West Indies

Richard A. Birdsey, Peter L. Weaver, and Calvin F. Nicholls



SUMMARY

Forest vegetation covers 13,000 ha or 38 percent of the land surface of St. Vincent Island. More than half of the forest area is successional, and there are substantial areas of palm, dwarf, and dry scrub forests. Nearly 5 percent of the land area is composed of mature, mostly undisturbed primary forest. *Inga vera, Licania ternatensis, Dacryodes excelsa,* and *Cecropia peltata* are common tree species in natural forests. *Hibiscus elatus, Pinus caribaea,* and *Swietenia macrophylla* are tree species that have been planted in St. Vincent. *Pinus caribaea* has attained the best growth rates.

ACKNOWLEDGEMENTS

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The Forest Resources of St. Vincent, West Indies

Contents

INTRODUCTION 1
HISTORICAL PERSPECTIVE 1
THE FOREST ENVIRONMENT 2
  Geology and Physiography 2
  Climate 4
  Soils 4
AGRICULTURE 5
WATER RESOURCES 5
NATURAL VEGETATION 6
  Climax Communities 6
  Secondary Communities 7
FOREST LEGISLATION AND LAND OWNERSHIP 7
FOREST PLANTATION SURVEY 7
  Plantation Description 7
  Management Recommendations 10
1984 FOREST INVENTORY 10
  Methods 10
  Forest Classification 11
  Forest Area 11
  Timberland Characteristics 12
  Species Composition 14
  Timber Volume 15
  Management Opportunities for Natural Forests 18
LITERATURE CITED 21
APPENDIX 22
  Reliability of the Data 22
  Definitions 22
  Tree Species Tallied in St. Vincent, 1984 23
  Metric Inventory Standards 25

Photos: Opposite page —*Plantation of* Hibiscus elatus.
Preceding page—*St. Vincent Forests.*

TABLES

1. Water supply sources and hydropower sites on St. Vincent 6
2. Summary of plantation species and sites surveyed; St. Vincent, 1984 8
3. Stand characteristics and growth rates of plantation species and sites surveyed; St. Vincent, 1984 9
4. Area by land class; St. Vincent, 1984 11
5. Proportion of forest land by watershed region and elevation; St. Vincent, 1984 11
6. Physiographic characteristics by forest class; St. Vincent, 1984 12
7. Forest characteristics by forest class; St. Vincent, 1984 13
8. Average number of live trees by diameter class and forest class; St. Vincent, 1984 13
9. Number of live trees by species and diameter class, ranked by basal area; young secondary forest, St. Vincent, 1984 14
10. Number of live trees by species and diameter class, ranked by basal area; secondary forest, St. Vincent, 1984 15
11. Number of live trees by species and diameter class, ranked by basal area; primary forest, St. Vincent, 1984 16
12. Volume of timber, growing stock, and sawtimber by species and tree size class; young secondary forest, St. Vincent, 1984 17
13. Volume of timber, growing stock, and sawtimber by species and tree size class; secondary forest, St. Vincent, 1984 18
14. Volume of timber, growing stock, and sawtimber by species and tree size class; primary forest, St. Vincent 1984 19
15. Volume of timber by class of timber and forest class; St. Vincent, 1984 19
16. Volume of sawtimber by species and log grade; St. Vincent, 1984 20
17. Averge number of trees by size class, tree class, and forest class; St. Vincent, 1984 20
18. Average basal area by size class, tree class, and forest class; St. Vincent, 1984 20

The Forest Resources of St. Vincent, West Indies

Richard A. Birdsey, Peter L. Weaver, and Calvin F. Nicholls

INTRODUCTION

This study was part of a comprehensive investigation titled "Forests of the Caribbean Islands: their role in development and their response to human and natural perturbations." The investigation had two major objectives. The first was to contribute to the assessment of natural resources (forests and watersheds) of selected Caribbean Islands by describing how these resources respond to environmental and human perturbations and by developing management prescriptions for these resources. The second objective was to provide training for natural resource agency personnel from Caribbean Islands.

This study responds to the first objective by providing a comprehensive overview of the forest resources of St. Vincent. St. Vincent was selected for detailed study because the island lacked quantitative forest resource information, and the island's forest resources are similar to forest resources of other Caribbean Islands. The second objective was supported during fieldwork when several St. Vincent Forestry Division employees were trained in forest measurement techniques. This report is intended to assist St. Vincent natural resource planners make rational and informed decisions regarding the development and use of forest lands.

Funding to conduct fieldwork in St. Vincent was provided by the United States Agency for International Development (U.S. AID). The work was carried out by personnel from the U.S. Forest Service, Southern Forest Experiment Station, in cooperation with the St. Vincent Forestry Division.

HISTORICAL PERSPECTIVE

The Arawak Indians apparently occupied many of the Caribbean Islands as early as 100 B.C. (Bennett 1975). They were sedentary and derived their subsistence from the cultivation of maize and root crops and through fishing. Around 1000 A.D., the Carib Indians from South America began to invade the islands from the south and by 1492 had reached the eastern end of Puerto Rico. This migration ceased with the arrival of the Europeans. By the 16th century, most of the Amerindian population had been exterminated.

The British, French, and Dutch invaders that arrived after St. Vincent's discovery were interested mainly in commercial agriculture and needed labor to operate the plantations. Slaves were brought from Africa, and by the 18th century, plantation agriculture reached its apex under the British. Subsequent migrations and intermarriage have resulted in the following ethnic population groupings in St. Vincent (U.S. AID 1982): African Negro, 65 percent; mixed, 20 percent; East Indian, 5 percent; European White, 4 percent; Amerindian, 2 percent; others, 4 percent.

Population growth on the Island since the mid-1800's has been classified into four major periods (Byrne 1969). From 1851 to 1881 and from 1911 to 1931, growth was moderate (fig. 1). The intervening period had little population growth. Starting in the 1930's, and in particular after World War II, population growth accelerated. The 1979 census showed 111,170 inhabitants for St. Vincent and the Grenadines, or a population density of about 285 people per square kilometer. About 7,000 people live in the Grenadines, a chain of islands belonging to St. Vincent.

The following is a brief sketch of major social events that have influenced the Island and its economy (Duncan 1970):

- 1498—St. Vincent was discovered by Columbus on the feast day of St. Vincent, according to the Spanish calendar, and was named in his honor.
- 1627—King Charles I of England assumed ownership of the island.
- Before 1750—Settlement began in the vicinity of Kingstown.
- 1763—Constitution bestowed by King George III, probably the day on which Kingstown was named.
- 1765—Botanical garden established in Kingstown for introduction of tropical species from other regions.
- 1793—Captain Bligh introduced breadfruit to the botanical garden, from which it spread to other areas in the neotropics.

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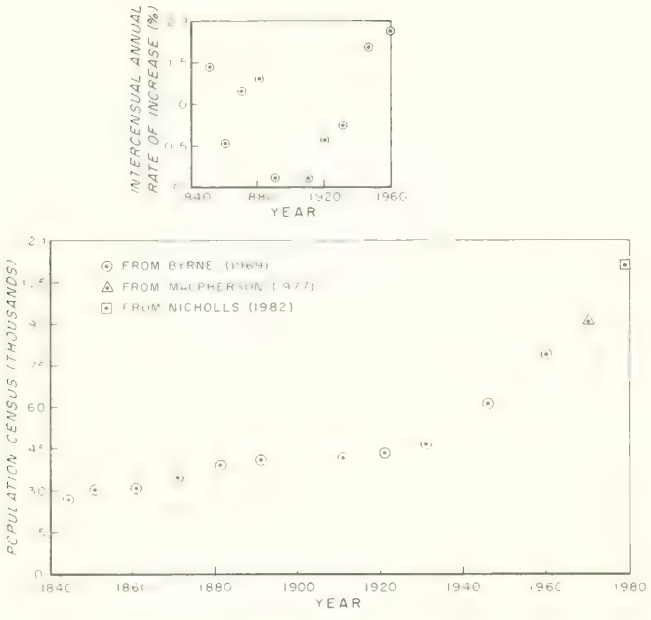

Figure 1.—*Population increase on St. Vincent, 1844 to 1979. Intercensual rate of increase balances birth, death, and migration.*

- 1822—Trade began with the United States.
- 1850—A decrease in the market price of sugar led to widespread planting of arrowroot on the island.
- 1930's—Population growth began to accelerate.
- 1953-54—Government warehouse in Kingstown was built. Bananas became the leading export crop.
- 1979—St. Vincent and the Grenadines became an independent State within the British Commonwealth after 10 years as an Associated State of the United Kingdom (U.S. AID 1982).

The botanical garden outside Kingstown, the oldest in the new world, deserves mention. It was established for "the cultivation and improvement of many plants now growing in the wild and the importation of others from similar climates" (Howard 1954). Alex Alexander was appointed director in 1785, and under his direction the garden reached its peak of maintenance and inventory, including 1,170 species of commercial and medicinal plants, esculents, fruits, valuable woods, and ornamentals (Howard and Howard 1983). Among the most renowned introductions were nutmeg and breadfruit trees from Captain Bligh's voyage after the Bounty mutiny. In the early 1900's agricultural experimentation was carried out in the garden, but by 1920, these functions had been transferred to nearby Camden Park. Currently, the botanical garden is a place of beauty with many interesting and economically important plants.

THE FOREST ENVIRONMENT

St. Vincent is located at 13°15′ N. latitude and 61°12′ W. longitude in the Caribbean Sea. The Island measures about 29 km long and 18 km wide at its maximum dimensions and encompasses about 345 km^2. The St. Vincent Grenadines, politically part of St. Vincent, consist of seven main islands stretching about 60 km to the south toward Grenada and occupy a total of 44 km^2. The largest and most proximate to St. Vincent is Bequia, which covers 18 km^2.

St. Vincent lies about 175 km west of Barbados and about 300 km north of the Paria Peninsula of Venezuela. The interior of the Island is steep and rugged and has not yet been traversed by a road. This land remains undisturbed and contrasts with the coastal zone and lower elevations where the Island's population resides.

The interrelations of geology, physiography, climate, and soils influence the structure and composition of the forests. Recurrent hurricanes and volcanic eruptions have had a considerable impact on the Island's vegetation, agriculture, and population.

Geology and Physiography

St. Vincent is entirely volcanic in origin (Evans 1973; Macpherson 1977). Its volcanoes have developed on a subsiding narrow submarine ridge about 1500 m below the current sea level (Hardy 1939). The first volcanic eruptions apparently occurred during the late Miocene and have continued intermittently, producing a series of volcanic piles, the oldest of which are in the southern part of the Island.

Soufriere in the north rises to 1220 m within 3 km of the coast (fig. 2). A deep trough across the Island separates the solitary cone from the remaining mountains to the south. The southern range extends for about 15 km. Highpoints are Richmond Peak at 1075 m, in the northwest; Mount Bisbane at 930 m, near the middle of the Island; and Grand Bonhomme at 960 m, in the south central part of the Island. The main ridge that runs down the central axis of the Island never dips below 600 m in elevation. Andesitic and basaltic agglomerates are common (Earle 1928). All rocks are Pleistocene to recent in origin (Watson and others 1958).

Soufriere, which dominates the northern part of the Island, erupted in 1718, 1812, 1902 (Howard 1962), and again in 1979 (Rowly 1979). It has apparently been erupting violently about once every 100 years for the last millennium. Historic eruptions have been characterized by nuees ardentes, or incandescent avalanches, that carbonize material in the absence of oxygen as they rush downslope. These eruptions have been accompanied by ashfall and mudflows. The

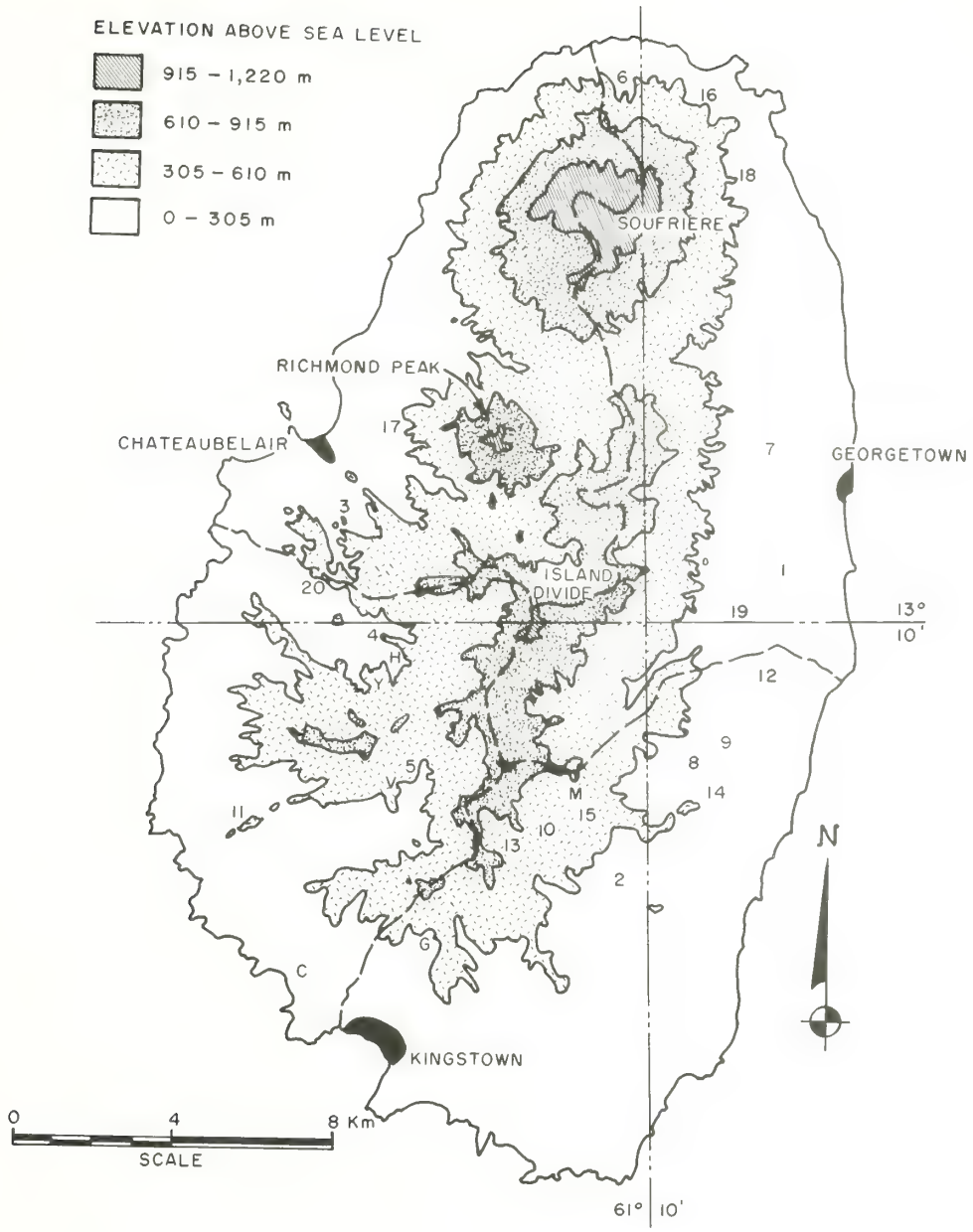

Figure 2.—*Topography of St. Vincent, with delineation of watershed regions (dashed lines). Location of water supply sources and hydropower sites are noted by numbers and plantations surveyed are noted by letters. Numbers are keyed to table 1 and letters are keyed to tables 2 and 3.*

crater lake inside the volcano disappeared after the 1979 eruption. Today deep, largely unvegetated gullies radiate from the summit.

During the Pleistocene, more than half a million years ago, St. Vincent was subject to marine submergence and intermittent uplift, creating a series of flat-topped terraces, of which seven are evident in the southeast (Watson and others 1958). Subaerial erosion has modified the terraces, producing a rolling landscape.

Towards the south, the land becomes progressively older and more mature, with deeper and wider valleys and lower ridges. The central mountains are characterized by sharp ridges and deep, steep-sided valleys. Numerous lateral ridges emanate from the central mountains. In the west, these are steep and separated by deep, narrow gorges. To the east, they slope more gently with wider, flatter valleys that form fairly extensive coastal plains in a few areas (Beard 1949).

Nearly 60 percent of the land surface lies below the 300-m contour and slightly more than one percent lies above 900 m. About 27 percent of the land lies between 300 and 600 m, with 13 percent between 600 and 900 m.

Climate

Daily and annual temperature fluctuations are minor because of the influence of the surrounding ocean. The 10-year record at the Botanical Garden in Kingstown showed a mean annual temperature of 26.7 °C, with a maximum of 31 °C (Wright 1929). The annual range of mean monthly temperatures was only about 2 °C, while the diurnal range of temperature was about 5 °C (Walker 1937).

The Island is influenced by tradewinds, particularly during the winter months. The annual migration of the equatorial convectional rains, however, provides a well-defined June through November rainfall maxima (fig. 3). Mean annual rainfall for the Botanical Garden determined from a 30-year record between 1894 and 1927 was 2615 mm and ranged between 2030 and 3500 mm (Wright 1929). The comparatively dry season from January to early May tends to be accentuated by soil porosity, steep slopes, and exposure to wind and sun (Beard 1944a).

St. Vincent lies just within the hurricane belt and averages one hurricane about every 25 years. The earliest on record occurred in 1780 and did a great deal of damage (Beard 1945). There was a storm of lesser intensity in 1819, severe ones in 1830 and 1886, a slight one in 1897, and a severe one in 1898. A moderate hurricane struck the Island in 1921. On September 8, 1967, and on August 8, 1980, respectively, hurricanes Beulah and Allen traversed the Island. During the latter 2 storms, only 2 people were killed, but more than 20,000 were affected by storm damage.

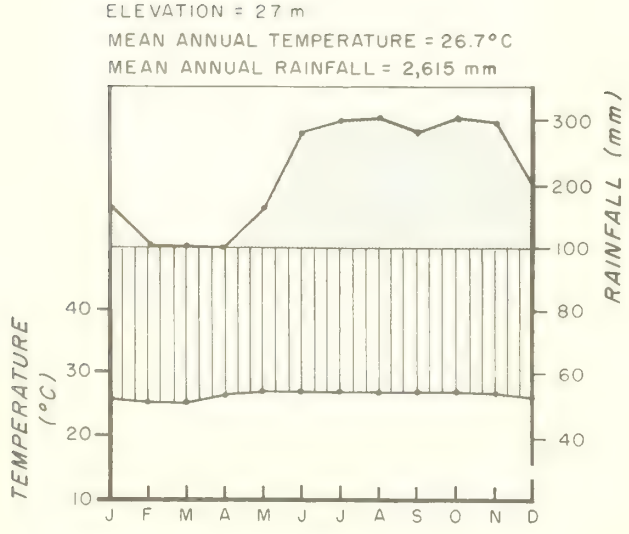

Figure 3.—*Climatic diagram for Kingstown, St. Vincent (adapted from Walker 1937). Temperatures are based on 10 years of record and rainfall on 30 years of record.*

The climate in the interior is cooler and wetter, but the lack of climatic stations means that estimates of rainfall are somewhat speculative. Available climatic maps (Macpherson 1977; Caribbean Conservation Association and others 1980) show a gradual increase in rainfall from about 1800 mm/yr in coastal areas to over 3800 mm/yr in most of the central mountains, with possible rainfalls in excess of 6000 mm/yr in the area surrounding the summits. Using the isohetal map (Caribbean Conservation Association and others 1980), assuming an average rainfall of 1800 mm/yr for the coastal areas and 6600 mm/yr for the summits, St. Vincent receives an average of about 3000 mm/yr over the entire island.

Examination of recent rainfall records shows several gaps in data collection that bias the data toward underestimates of total rainfall and make comparisons among stations tenuous. Similar observations were made at an earlier date (Walker 1937).

Soils

The soils of St. Vincent are derived mainly from loose, fragmental volcanic ejecta such as boulders, stones, cinders, sand, and ash (Hardy 1939). There are three major soil groups:

Coastal plain and valley alluvial soils—These soils occupy flatland near the coast, valley floors, and mouths of small estuaries. The material from which they are derived consists of loose, black, volcanic sand transported from higher elevations. They are fertile and subject to little erosion.

Recent volcanic ash soil—These are incipient soils recently derived from fragmental ejecta (in Hardy's 1939 study these soils were from the 1902 and earlier eruptions).

Yellow earth soil—These soils are found on the rest of the Island and display varying degrees of maturity and considerable variation in physical features and natural history.

In general, Island soils have been described as immature with a high content of unaltered minerals, markedly uniform in vertical profile, and containing low contents of weathered products. Furthermore, they are neutral to slightly acidic in reaction, contain medium-high amounts of organic matter, and are highly permeable to water. The rate of solution of mineral components is low, and the contents of available potash and phosphate are low. They have a low saturation capacity, low content of exchangeable bases, and a high degree of base saturation (Hardy and others 1934). Although such soils would not be

expected to erode rapidly because of their high permeability to water, sheet, rill, gully erosion, and landslip are observable today in different parts of the Island.

AGRICULTURE

St. Vincent's economy has traditionally been dependent on export crops. During the 1700's, sea-island cotton was grown extensively on the Island, but at the beginning of the 1800's, plantation-grown sugar cane became the foremost crop. After 1850, following emancipation, sugar production declined. Concurrent with its decline, the cultivation of arrowroot as a cash crop was started by many small farmers. At the turn of the century, arrowroot and cotton continued as the leading export crops of the island.

Before 1897, most of the agricultural land belonged to large estates. In that year, a Royal Commission recommended that the government purchase large estates and partition them among small farmers (Beard 1944a). The distribution of land by size of ownership as of 1944 for 177 km^2 of privately owned land was as follows: under 2 ha, 15 percent; 2.1 to 4 ha, 8 percent; 4.1 to 20 ha, 8 percent; 20.1 to 40 ha, 3 percent; 40.1 to 400 ha, 58 percent; and greater than 400 ha, 8 percent.

Current statistics from the Ministry of Trade, Industry and Agriculture (1981) concerning the production of agricultural crops on the Island were summarized for 1981 (fig. 4). About 4000 ha, or 36 percent of the area for which statistics were available, were planted in starchy root crops. Bananas, coconuts, sugar, and arrowroot were the next most common crops.

The total value of crop production for 1981 was $23,408,580 (U.S. dollars) for the 22 crops evaluated. Bananas were the most important, with about 48 percent of the total. Starchy root crops, with about 12 percent; coconuts, with over 11 percent; mangoes, with about 6 percent; and arrowroot and ginger, with about 5 percent each, were the next most valuable crops.

Dietary staples include rice, sweet potatoes, yams, and cassava, which are accompanied by fish, pulses, other vegetables and fruits, cheese and other milk products, and meats. Bananas, the most important export crop, and arrowroot, the second most important export crop, are grown on small farms that average between 0.5 and 1.0 ha in size. St. Vincent arrowroot produces a high-quality starch that is used for the manufacture of computer paper and in home and pharmaceutical products. Coconuts are grown principally on large farms while vegetable and fruit production takes place on small properties for home use and sale. Food crops include sweet potatoes, tannias, dasheen, eddoes, carrots, yams, pumpkins, and mangoes (U.S. AID 1982). The majority of agricultural

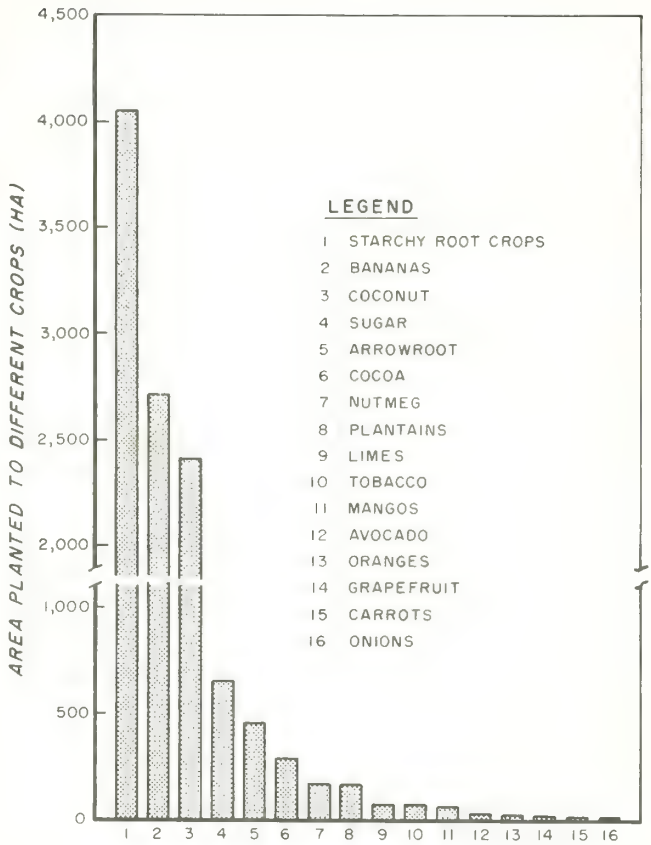

Figure 4.—*Agriculture production on St. Vincent. Data based on statistics compiled by the Ministry of Trade, Industry and Agriculture, 1981.*

production is aimed at the export market in the United Kingdom, other Caribbean islands, and North America.

WATER RESOURCES

St. Vincent is a small island with a high population density in the south. A continuous water supply is a basic need that must be met with the limited water resources available locally. Water supply problems on nearby islands indicate that St. Vincent's water resources should be carefully assessed.

The rivers of St. Vincent are short and straight. In the mountains, the steep courses run through deep, narrow valleys. At lower elevations, they broaden into small delta-shaped alluvial flats. The largest river on the Island is the Colonarie and the second largest is the Wallabou.

If the estimate of 3000 mm/yr of rainfall for the entire island is reasonably accurate, then St. Vincent receives 1.035×10^9 m^3 of water on its surface each year. No estimates are available for runoff, evapotranspiration, or ground water storage.

Twenty major water supply sources and hydropower sites are located in several watersheds circum-

scribing the central mountains (fig. 2, and table 1). Combined, these supply sources have a dry intake capacity of 17.1 million l/day and a wet intake capacity of 29.4 million l/day.

NATURAL VEGETATION

The "Flora of St. Vincent and adjacent islets" lists 1,150 species, with about 250 trees and shrubs (Anon. 1893). Subsequently, much botanical work was done in the forests of St. Vincent and elsewhere in the Caribbean (Beard 1942, 1944a, 1944b, 1944c, 1944d, 1949; Stehle 1945). The primary interest was in the trees and forests of the region. Later, the vegetation of the Grenadines was studied, including the islands belonging to St. Vincent (Howard 1952). Descriptions of many of the tree species found in St. Vincent, their locations elsewhere in the hemisphere, and their potential uses have been documented (Little and Wadsworth 1964; Little, Woodbury and Wadsworth 1974). Many have been classified as valuable native and plantation sawtimbers (Longwood 1961, 1962; Fraser 1957). The following summary of the natural vegetation is based on Beard's (1949) classification, which is still largely applicable (fig. 5).

Table 1.—*Water supply sources and hydropower sites on St. Vincent*[1]

Number[2]	Name	Number and type of intakes	Intake capacity[3]	
			Dry	Wet
1	Byera	1 spring	57	57
2	Camel	2 springs	151	163
3	Chateaubelair	1 river	303	454
		2 springs		
4	Cumberland River[4 5]	1 river	3,785	6,359
5	Dalaway[6]	2 rivers	5,678	10,220
6	Fancy	1 river	189	189
7	Georgetown	3 springs	360	360
8	Greiggs	2 springs	284	379
9	Higher Lowmans	1 spring	379	379
		1 river		
10	John Hill	1 river	644	946
11	Layou	1 spring	379	568
12	Lively	1 spring	76	114
13	Majorca	1 river	1,893	3,218
14	Maroon	1 river	151	757
15	Montreal	1 spring		
		4 rivers	1,514	3,785
16	Owia	1 river	189	189
17	Richmond[5]			
18	Sandy Bay	1 river	341	341
19	South Rivers[5]	2 springs	681	833
20	Spring Village	1 spring	106	106

[1]Forestry Division, Ministry of Trade, Industry and Agriculture, Kingstown, St. Vincent.
[2]Numbers are coded to figure 2.
[3]In thousands of liters per day.
[4]Includes Hermitage, Convent, and Grove.
[5]Hydropower sites.
[6]Located in the Vermont area.

Climax Communities

Rain Forest.—The rain forest occupies small areas between 350 and 500 m in elevation, principally in the headwaters of the Colonarie, Cumberland, and Buccament Valleys. The forest averages about 30 m tall, is closed and dense, has two strata of trees, and is somewhat patchy due to storm damage and topography. Windward and leeward forests are similar in composition with the exception of *Prestoea montana,* which forms about 35 percent of the stems to the windward and is virtually absent to the leeward. Other canopy dominants are *Dacryodes excelsa, Lauraceae spp., Meliosma herbertii, Micropholis chrysophylloides,* and *Sloanea caribaea,* which collectively constitute over 50 percent of the stems.

Elfin Woodland.—The elfin woodland or dwarf forest occupies exposed summits above 500 m on both sides of the central mountains. The forest is short, 4 m or less in height, and composed of gnarled trees that are covered with moss and epiphytes. The principal tree species include *Charianthus coccineus, Didymopanax attenuatum, Freziera hirsuta, P. montana, Inga laurina, Weinmannia pinnata, Ficus spp.,* and *Clusia spp.*

Littoral Woodland.—The littoral woodland is found in limited areas adjacent to the sea. The forest varies

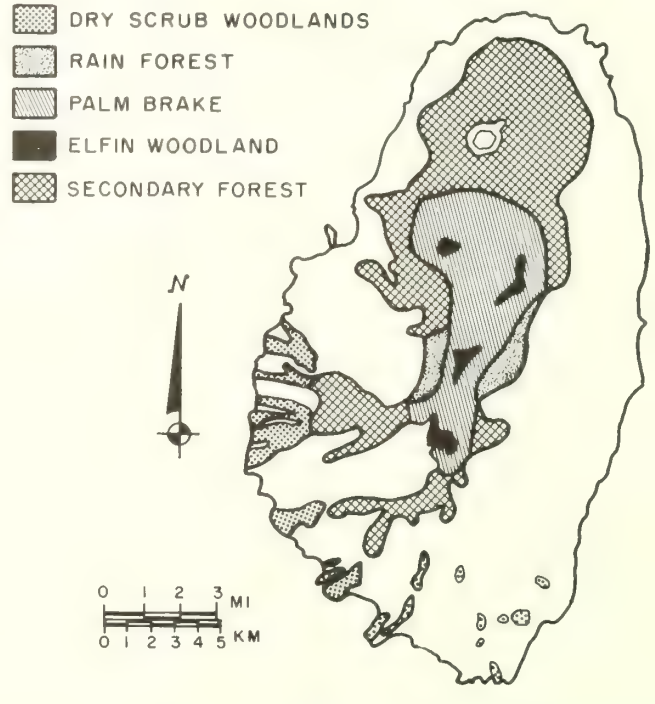

Figure 5.—*Location of major forest types on St. Vincent according to Beard's classification (1949).*

in height depending on exposure but usually does not exceed 8 m. *Coccoloba uvifera, Rheedia spp.,* and *Tabebuia pallida* are common dominants.

Mangrove Forest.—There is a very small area of mangroves on the south coast that contains *Rhizophora mangle* and *Avicennia germinans.*

Secondary Communities

Palm Brake.—The palm brake occupies exposed areas above 500 m on both sides of the mountains. About 70 percent of the stems are palms that reach 12 m tall in some places. The remaining species are second-growth pioneers or occasional trees from the rain forest.

Secondary Rain Forest.—The secondary rain forest is generally located above areas of permanent cultivation and below the rain forest. Several areas are partially cultivated by farmers and contain a large component of secondary species including *Chimarrhis cymosa, Sapium caribeum, I. ingoides, Cecropia peltata, Freziera hirsuta, Ochroma pyramidale, Cordia sulcata,* and *Lauraceae spp.* More advanced succession contains a greater number of rain forest species.

Dry Scrub Woodlands.—Dry scrub woodlands occupy uncultivable land on precipitous rocky slopes where luxuriant forest never existed. It has been heavily felled for timber and fuelwood. Dominant tree species include *Bursera simaruba, Pisonia fragrans,* and *Acrocomia spp.* King's Hill reserve in the southeastern part of the island is a unique exception. Largely undisturbed since its creation, a forest has developed that reaches 20 m in some areas. In addition to the hardwoods mentioned above, *T. pallida, Swietenia mahagoni, Hymenaea courbaril, Pouteria multiflora, I. laurina, Mastichodendron foetidissimum, Brosimum alicastrum,* and *Lauraceae spp.* are found as dominants.

With recurrent eruptions of Soufriere, the area surrounding the mountain is in a constant state of disturbance ranging from exposed soil immediately after eruption to fairly advanced stages of succession after many years without vulcanism. Because of the elevational gradient, plant communities that would become established in the absence of disturbance range from rain forest at the lowest elevations through elfin woodland at the summit. Succession follows a general displacement of communities upward as it progresses. This succession has been described by several authors (Anderson 1908; Beard 1945, 1949, 1976; Howard 1962; Sands 1912).

FOREST LEGISLATION AND LAND OWNERSHIP

The principal ordinances concerning forests on St. Vincent as listed in Beard (1944a) are:

The King's Hill Enclosure Ordinance 82 of 1926 (No. 5 of 1791): reserves about 22 ha of woodlands on King's Hill for "the purpose of attracting the clouds and rain . . . for the benefit and advantage of the owners and possessors of lands in the neighborhood thereof." Penalties are prescribed for cutting timber and squatting.

The Charcoal Ordinance 98 of 1926 (No. 5 of 1906): prescribes penalties for unlawful burning of charcoal and is used to control charcoal burning on crown lands.

Crown Land Ordinance 77 of 1926 (No. 3 of 1906): deals mainly with surveys and squatting on crown lands and also contains provisions for a "Superintendent of Crown lands"; a means of making regulations for management, sale, lease, and prevention of squatting on the lands and prescribes penalties for squatting and unauthorized cutting.

Proclamation of August 22, 1912: reserves all crown lands above 1,000 feet elevation to protect them from any act that would be prejudicial to forest conservation. This area has been estimated at 168 km^2, slightly less than half the island.

At the time Beard drafted his statements, it was felt that legal protection of the forests was inadequate. Since that time, cutting and clearing in the forest has continued, mainly for subsistence agriculture. Steep slopes, heavy rainfall, and lack of access roads, however, have restricted the invasion of crown lands. Lands classified as "alienated" or private total 177 km^2—slightly more than half the island.

FOREST PLANTATION SURVEY

Plantation Description

Of the 50.6 ha of plantations for which we could find records, *Hibiscus elatus* accounted for a little over 70 percent of the total area (fig. 6). *Pinus caribaea* and *S. macrophylla* accounted for another 18 percent of the plantations. About a third of the plantations were established in 1968-69 and about 40 percent in 1982, with a steady rate of 2 to 4 ha planted in most intervening years. The increase in activity starting in 1981 was mainly due to financial assistance from U.S. AID under its Basic Human Needs Program, administered by the Caribbean Development Bank. At the First Workshop of Caribbean Foresters, *H. elatus* was reported to occupy 75 ha on St. Vincent; *P. caribaea,* 30 ha; and *S. macrophylla,* 18 ha (Nicholls 1982).

Plantation measurements were made at 19 different sites (table 2). The methods used to determine standing volumes and growth rates were presented at the Second Workshop of Caribbean Foresters (Weaver and Valenta 1984). Stand volume varied considerably by species, site, age, and previous silviculture and ranged from 5.6 m^3/ha for 9-year-old *C. sulcata* at Government House to a surprising 575 m^3/ha for 21-

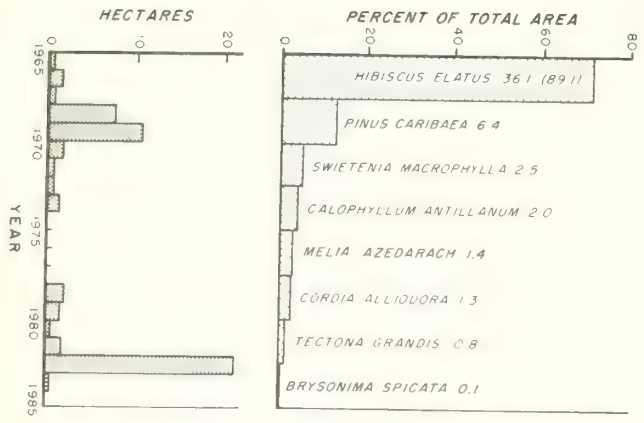

Figure 6.—*Planting records for St. Vincent. (Top) Percent of total area planted by species (species name followed by actual area planted in ha). (Bottom) Chronology of planting since 1965 without regard to species. Records may not be complete.*

year-old *P. caribaea* at Hermitage (table 3). In Young Man's Valley, where all the species were planted in 1969 and thinned in 1976, *P. caribaea* attained the greatest mean diameter, mean height, and total volume. At Hermitage, where plantings were done in 1962–63 and thinnings in 1976, again *P. caribaea* showed the largest mean dimensions and volume. The latter plantation was located on a terrace and appeared to have been well tended. Both of these factors contributed to the fine growth. The *S. macrophylla* plantations at Hermitage differed in mean diameter, mean height, and total volume, with the thinned stand showing better growth than the unthinned stand.

At Vermont, *Calophyllum antillanum, H. elatus,* and *P. caribaea* were established between 1971 and 1973 and had never been thinned. *Pinus caribaea* again had the largest dimensions and volume. *Hibis-*

Table 2.—*Summary of plantation species and sites surveyed; St. Vincent, 1984*[1]

Site and species[2]	Planted	Thinned	Trees	Plots	Comments
	------- *Date*[3] -------		--*No. measured* --		
Y- Young Man's Valley					
Cordia alliodora	1969	1976	22	3	midslope; stand open
Hibiscus elatus	1969	1976	20	1	bottomland; stand dense
Pinus caribaea	1969	1976	28	1	mid-to-upper slope; stand very dense
H- Hermitage					
H. elatus	1962–63	1975	25	2	midslope
P. caribaea	1962–63	1975	18	1	bottomland terrace
Swietenia macrophylla	1962–63	1975	19	1	midslope; stand dense
S. macrophylla	1962–63	.....	22	1	mid-to-lower slope; stand very dense
G- Government House					
C. alliodora	1975	.....	7	2	midslope; stand open
S. macrophylla	1969–70	1975	28	2	midslope
V- Vermont					
Calophyllum antillanum	1973	.....	9	1	midslope; trees branchy; understory
H. elatus	1971–72	.....	15	2	midslope
P. caribaea	1973	.....	33	2	mid-to-lower slope
M- Montreal					
H. elatus	1966–67	1974	12	1	steep midslope
H. elatus	1966–67	1974	11	1	bottomland
P. caribaea	1967	1979	14	1	gentle midslope
P. caribaea	1967	1979	25	1	gentle midslope
P. caribaea	1967	1982	20	1	exposed hilltop; considerable wind
C- Camden Park					
S. mahagoni	.....	.....	96	3	mid-to-upper slope
Tabebuia pallida	.....	.....	32		
Total			456	27	

[1]All are plantations except for Camden Park, which is naturally regenerated secondary forest. All plantations were originally planted in 1.8- by 1.8-m spacings.

[2]Letters preceeding site name are coded to figure 2.

[3]Dates derived from records and field personnel. Dashes indicate missing dates or no thinning.

[4]Both species at Camden Park were recorded from 0.1-ha plots.

cus elatus and *C. antillanum* had nearly equal diameter and volume, while the height of *H. elatus* averaged 2 m taller.

At Montreal, the plantations of *H. elatus* and *P. caribaea* were established in 1966 and 1967. The *H. elatus* was thinned in 1974. One of the *P. caribaea* plantations was thinned in 1979 and another in 1982, while the last plantation remained unthinned. The *H. elatus* growing on the slope had larger dimensions and volume than that on the bottomland. The *P. caribaea* thinned in 1979 had greater mean diameter and mean height but less volume than the unthinned stand, both of which were on gentle midslopes. The remaining *P. caribaea* stand, thinned in 1982, was situated in an area exposed to wind and had less height and volume than the other stands.

In a secondary forest at Camden Park, *S. mahagoni* constituted 75 percent of the stems (table 2). Mean diameter and height were considerably less than *T. pallida*. Basal area for both species combined was 17.8 m^2/ha, and the total volume was 134.8 m^3/ha.

Diameter growth rates ranged between 0.62 and 2.06 cm/yr, height growth between 0.66 and 1.80 m/yr, and volume growth between 0.42 and 28.76 m^3/ha/yr for all species and sites combined (table 3). In general, the best growth was attained by *P. caribaea* and the poorest by *Cordia alliodora*. *H. elatus* showed the least variation in diameter, height, and volume growth regardless of age, site, or silvicultural treatment. On the other hand, *S. macrophylla* appeared to have better diameter and volume growth when thinned.

Although the scope of this survey of forest plantations was limited, some preliminary observations are possible:

Swietenia macrophylla showed poor form on most sites, with low branching and excessive crown development. Most of this poor form is probably attributable to a shoot borer (*Hypsipyla grandella*) infestation. Lack of a clear stem will seriously reduce the stand value and utility at maturity.

About 70 percent of the stands have high basal

Table 3.—*Stand characteristics and growth rates of plantation species and sites surveyed; St. Vincent, 1984*

Site and species[1]	Mean dimensions and mean annual growth rates							
	Diameter		Height		Basal area[2]		Total woody volume[3]	
	Cm	*Cm/yr*	*M*	*M/yr*	M^2/*ha*	M^2/*ha/yr*	M^3/*ha*	M^3/*ha/yr*
Y- Young Man's Valley								
Cordia alliodora	15.4 (1.0)[4]	1.13 (0.07)	12.8 (0.4)	0.95 (0.03)	16.8	1.24	33.7	2.50
Hibiscus elatus	14.7 (1.0)	1.09 (0.07)	15.5 (0.7)	1.15 (0.05)	45.9	3.40	100.7	7.44
Pinus caribaea	23.4 (0.8)	1.74 (0.06)	18.4 (0.6)	1.36 (0.05)	64.3	4.76	281.3	20.84
H- Hermitage								
H. elatus	23.6 (0.8)	1.17 (0.04)	20.8 (0.4)	1.03 (0.02)	28.7	1.44	172.4	8.62
P. caribaea	35.6 (1.0)	1.78 (0.05)	27.3 (0.7)	1.36 (0.03)	41.3	2.06	575.2	28.76
Swietenia macrophylla	30.6 (1.4)	1.53 (0.07)	19.2 (0.4)	0.96 (0.02)	43.6	2.18	395.3	19.76
S. macrophylla	20.4 (1.0)	1.02 (0.05)	18.6 (0.5)	0.93 (0.02)	50.5	2.52	215.2	10.76
G- Government House								
C. alliodora	8.4 (0.7)	1.11 (0.10)	8.8 (0.5)	1.18 (0.07)	8.0	1.07	5.6	0.75
S. macrophylla	23.9 (0.9)	1.77 (0.07)	15.2 (0.3)	1.12 (0.02)	32.4	2.40	149.2	11.05
V- Vermont								
Calophyllum antillanum	11.7 (0.7)	1.23 (0.08)	10.8 (0.4)	1.13 (0.05)	20.6	2.17	23.1	2.43
H. elatus	12.1 (0.8)	1.10 (0.07)	12.7 (0.6)	1.15 (0.05)	17.2	1.56	23.2	2.10
P. caribaea	19.6 (0.7)	2.06 (0.07)	17.1 (0.6)	1.80 (0.06)	37.9	3.99	108.6	11.43
M- Montreal								
H. elatus	21.0 (1.1)	1.27 (0.07)	20.3 (0.7)	1.23 (0.04)	25.7	1.56	131.1	7.94
H. elatus	18.4 (1.4)	1.12 (0.08)	19.0 (0.7)	1.15 (0.04)	25.2	1.53	93.1	5.64
P. caribaea	21.2 (0.8)	1.37 (0.05)	19.2 (0.4)	1.24 (0.03)	32.1	1.94	115.0	7.42
P. caribaea	18.9 (0.4)	1.22 (0.03)	14.8 (0.4)	0.95 (0.03)	57.4	3.48	125.8	8.11
P. caribaea	18.9 (0.4)	1.22 (0.04)	12.0 (0.3)	0.77 (0.02)	45.9	2.78	82.8	5.34

[1]Letters preceeding site names are coded to fig. 2.

[2]Basal areas were read with a BAF 10 prism (each intercepted tree = 2.3 m^2/ha). Basal areas of harvested trees were not included.

[3]Above ground (branches + bole), outside bark volumes for dicots were determined by formula (Dawkins 1961). For *P. caribaea*, outside-bark bole volumes were derived by formula (Vorhoeve and Bower n. d.). Volumes of trees already harvested were not included.

[4]Numbers in parentheses are standard errors.

areas in excess of 25 m^2/ha. Although *P. caribaea* and *H. elatus* are narrow-crowned species able to tolerate high stem densities for several years, continued development without thinning will result in slower growth on the rotation trees and high stand mortality. Timber production on existing stands could be improved with thinning, but without studies using different spacings and thinning regimes on several sites, it is difficult to prescribe the best management practices for a complete rotation. Unthinned *S. macrophylla* at Hermitage has already begun to slow in diameter growth because of high stand density.

Incomplete records make assessment of growth, development, and stand volumes extremely difficult. Accurate data on plantation establishment dates, original spacings, dates and types of thinnings, and recurrent measurement of selected sample plots for growth analyses are needed.

Management Recommendations

Except for Government House, the forest plantations are concentrated high in upper watersheds where clearing and cultivation of subsistence crops is underway. Most of the land is government property that has been reclaimed through the establishment of plantations. Efforts to increase plantations in these areas should continue both for the provision of lumber and to deter further advance of cultivation into the interior of the Island.

Many of the plantations are very dense. The close spacing traditionally used throughout the Island offers a chance for selection of better stems after 4 or 5 years. Thinning at this time would enhance the development of better trees and maintain good growth over a longer period of time. Other spacings and thinning regimes should be studied. Perhaps the 1981-82 plantations established with U.S. AID assistance could provide a starting point for silvicultural research in cooperation with outside institutions.

An alternative method for the establishment of *S. macrophylla* should be investigated. The tree's high value and utility assure a ready market. Shoot borer infestation may be diminished by line planting widely spaced *S. macrophylla* interspersed with other fast growing timber species. In subsequent thinnings, the better formed trees could be favored.

1984 FOREST INVENTORY

The St. Vincent forest inventory was designed to provide two kinds of information: estimates of forest area for various forest classes and statistics describing the composition of "timberland" or forests with some commercial potential. The presentation of data in commercial terms should not be construed as a recommendation for exploitation or management of natural forests. Rather, the information is intended to be used as background material for planning and research concerning forest resources on the Island. Natural forests in St. Vincent have important functions, such as watershed and wildlife habitat protection and provision of tourism and recreation opportunities. Any decisions that affect these unique forests must be carefully made.

The inventory was designed as a reconnaisance survey to provide Island-wide forest resource information. The data were derived from photointerpretation and field observations at sample locations and represent "average" conditions within forest communities on the Island. Since the forests are quite heterogeneous due to varying levels of human impact and diverse site conditions, the information cannot be used to describe conditions or develop management plans for specific sites.

Methods

The data on forest areas, timber volume, and species composition were obtained by a sampling method involving a land-cover classification on aerial photographs and on-the-ground measurements. A dot count method was used to obtain an initial estimate of area by land-cover class. This estimate was adjusted on the basis of a ground check of actual land cover at each of the sample locations.

Sample locations were selected on a base map at the intersections of a grid of lines spaced 2 km apart. Each sample location was visited to determine cover class. The center of each forest location classified as timberland was located by running a computed azimuth and distance from an identified starting point. Detailed field measurements were taken at all accessible timberland locations.

A cluster of three permanent sample plots was established at each timberland location. Sample plots were located 25 m apart. At each sample plot, trees 12.5 cm and larger in diameter at breast height (d.b.h.) were tallied on a variable-radius plot, with each tree representing 2.5 m^2 of basal area per hectare. Trees less than 12.5 cm in d.b.h. were tallied on a fixed-radius plot of approximately 40 m^2 around the first sample plot and 15 m^2 around the other two sample plots. This sample plot design was determined to be efficient for similar forest conditions in Puerto Rico (Birdsey 1983).

Each sample location was classified by numerous site characteristics. Each sample tree 12.5 cm and larger in d.b.h. was measured and assessed to determine timber volume and quality. Species was determined for each sample tree. Detailed field measurements were assembled into a handbook. All definitions and inventory standards are listed in the appendix to this report, along with a species list and some useful conversion factors.

All field data were recorded on tally sheets, transferred to the computer, and edited for errors prior to compilation. Errors were kept to a minimum by careful training, diligent field work, and a detailed edit procedure that checks all items for consistency and reasonableness.

All field work was done in 1984 between January and April. Prior to field work, photointerpretation for area estimation was done using 1:25,000 scale panchromatic photography from a photographic mission in January 1981.

A total of 3,168 photo samples were classified, and 88 ground locations were checked. Detailed forest measurements were taken at 57 sample plots clustered at 19 sample locations.

Forest Classification

The forest classification corresponds to the natural vegetation communities described by Beard (1949). These communities can be recognized with reasonable accuracy on the aerial photographs and verified on the ground. Timberland is composed of those forest classes occupying sites that can be used for timber production. Timberland classes in St. Vincent include the primary forest and successional communities, divided into young secondary and secondary. Plantations are included in timberland since they are located on sites that would otherwise support one of the timberland classes.

Forest land other than timberland includes forest classes occupying sites that are sensitive to disturbance and would generally not be productive. This forest land includes the palm forest and dwarf (elfin) forest, found on exposed sites above 500 m; and the dry scrub forest, found on very steep, rocky slopes or adjacent to the sea. Maintenance of forest cover on these sites is critical to protect water catchments from severe erosion.

Table 4.—*Area by land class; St. Vincent, 1984*

Land class	Area	
	Hectares	*Percent*
Timberland		
Young secondary forest	3,570	10.5
Secondary forest	3,706	10.9
Primary forest	1,632	4.8
Plantation forest	34	0.1
Total	8,942	26.3
Other forest land		
Palm forest	1,734	5.1
Dwarf forest	952	2.8
Dry scrub forest	1,326	3.9
Total	4,012	11.8
Nonstocked land[1]	2,754	8.1
Nonforest land	18,292	53.8
Total land[2]	34,000	100.0

[1]Land deforested due to natural disturbance and not currently in nonforest use.

[2]Values for total land from Nicholls 1982.

Table 5.—*Proportion of forest land by watershed region and elevation; St. Vincent, 1984*[1]

Watershed region	Elevation[2]	
	Below 305 m	Above 305 m
	Percent	
Northwest	56	94
Southwest	36	69
Southeast	4	32
Northeast	6	83

[1]Forest land includes nonstocked land; watershed regions are outlined in figure 2.

[2]The 305 m used here equates to the proclamation that reserves all crown lands above 1000 ft.

Forest Area

Forests cover 13,000 ha or 38 percent of the land surface of St. Vincent (table 4). Secondary or successional forests account for more than half of all forest land. Nearly 5 percent of the land area is composed of mature, mostly undisturbed primary forest. This and the undisturbed palm and dwarf forests are among the largest remaining contiguous areas of relatively unaltered ecosystems in the Lesser Antilles (Putney 1982). Located in the rugged central mountains, the primary forest is the home of several endangered species, including the St. Vincent parrot *Amazona guildingii*. The parrot habitat is protected as a sanctuary, and these protected lands include all of the primary rain forest.

Forest area has declined slightly over the past 10 years, based on an FAO estimate of 41.2 percent of the land area in forest in 1974 (Food and Agricultural Organization of the United Nations 1975). The change is due to the 1979 eruption of Soufriere that resulted in 2750 hectares of nonstocked or bare land.

The distribution of forest land in St. Vincent is largely the result of settlement patterns. Most of the land suitable for agriculture is found at elevations below 300 m and has been cultivated for many years. Forest cover is nearly absent below 300 m on the eastern, or windward, side (table 5). The western, or leeward, side is much more rugged; the area below 300 m includes many pockets of forest on land too steep to cultivate. The northwest region is the most rugged and contains the highest proportion of forest.

Although all land above 300 m was reserved by law for many years to protect the forest, many parcels are leased for nonforest use. Few roads penetrate the interior, and despite encroachment problems, the remote area has retained a high proportion of forest cover. The main exception is in the Southeast, where only 32 percent of the land above 300 m is forest land. Here a fairly dense road network penetrates well into the reserved land. This region would likely be the first to experience water supply problems during a drought due to the high population density, sparse forest cover, and location of six water intakes.

Timberland Characteristics

Of the three major timberland classes, primary rain forests are located at the highest elevations and farthest distance from roads (table 6). Young secondary forests are more accessible and tend to be associated with recent agricultural activity. The average distance to water for all timberland is less than 100 m.

Both young secondary and secondary forests have similar basal areas, but the young secondary forests average nearly twice the number of stems (table 7). The younger forests have smaller average diameters and canopy heights. These statistics suggest that, in the successional process, the disturbed site is quickly occupied by a large number of small stems that compete vigorously until a secondary stand is well established. The secondary forest then matures over a long period, accumulating biomass to reach a potential basal area of more than 30 m^2/ha.

At some point during the maturation process, the number of small stems again begins to increase as shade-tolerant understory species and saplings of canopy species become established. The primary forest develops the appearance of two distinct strata, with the upper canopy height averaging more than 25 m above the ground. The basal area of saplings is significantly greater than that of poletimber, with large sawtimber-size trees clearly dominating the available growing space (fig. 7).

Wood volume steadily accumulates over time. Most of the volume in young secondary forests is found in large residual trees that have outlasted surrounding disturbances. Young secondary forests average two large trees per hectare in the 75-cm d.b.h. and larger classes, and no trees in the 50- to 70-cm d.b.h. classes (table 8). Secondary forests have 18 and primary forests 43 trees/ha whose d.b.h. is greater than 50 cm.

Much of the apparent variability in these statistics is due to the intermingling of the three timberland

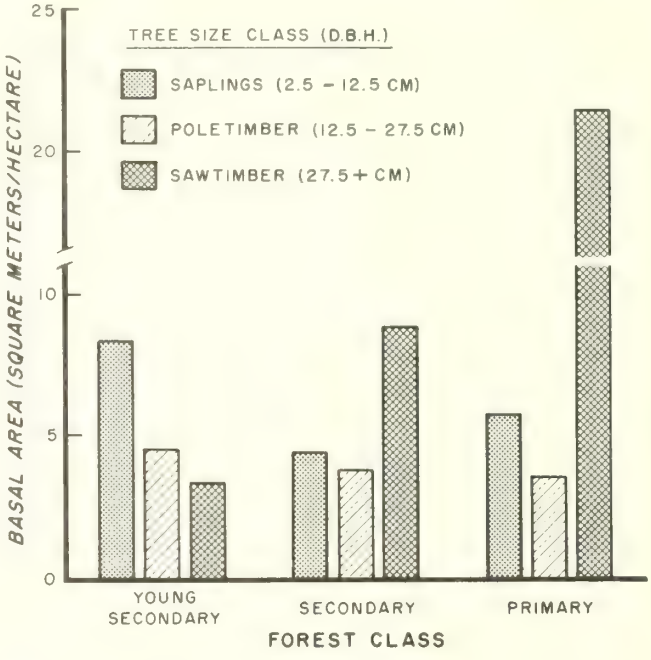

Figure 7.—*Average basal area by forest class and tree size class; St. Vincent timberland.*

Table 6.—*Physiographic characteristics by forest class; St. Vincent, 1984*

Characteristic (units)	Statistic	Forest class			All classes
		Young secondary	Secondary	Primary	
Elevation	Mean	327	379	490	377
(meters)	Range	220–390	130–690	390–550	130–690
Slope[1]	Mean	73	48	57	59
(percent)	Range	50–90	0–90	30–70	0–90
Distance to road[2]	Mean	120	214	373	204
(meters)	Range	100–290	70–500	100–800	100–800
Distance to water[3]	Mean	90	95	93	93
(meters)	Range	30–250	10–300	50–150	10–300

[1]Average slope at each plot location.
[2]Distance to nearest all-weather road.
[3]Distance to nearest stream or body of water.

Table 7.—*Forest characteristics by forest class; St. Vincent, 1984*

Characteristic	Statistic	Forest class			All classes
		Young secondary	Secondary	Primary	
Basal area[1] (m^2/ha)	Mean	16.3	16.9	30.7	19.0
	Range	3.3–25.7	8.3–23.7	19.7–38.2	3.3–38.2
Number of trees[1] (stems/ha)	Mean	2758	1506	2323	2129
	Range	67–5076	85–2453	1266–3743	67–5076
Mean diameter[2] (cm)	Mean	9.1	12.0	13.5	11.2
	Range	5.7–11.2	9.6–16.0	11.4–14.9	5.7–16.0
Mean canopy height[3] (m)	Mean	13.7	20.0	25.8	18.5
	Range	8.4–23.9	12.7–28.5	22.9–30.0	8.4–30.0
Total volume[4] (m^3/ha)	Mean	77.4	150.8	357.9	156.7
	Range	24.7–122.0	54.4–273.6	215.0–481.5	24.7–481.5
Timber volume[5] (m^3/ha)	Mean	52.7	98.6	251.4	106.2
	Range	11.8–97.9	53.9–171.6	130.5–342.2	11.8–342.2

[1]All trees 2.5 cm d.b.h. and larger.
[2]Quadratic mean at each plot location.
[3]Based on dominant and codominant trees.
[4]Total overbark volume of trees 12.5 cm d.b.h. and larger using equation by Dawkins (1961).
[5]All sound wood of trees 12.5 cm d.b.h. and larger, from stump to a 10-cm minimum diameter.

Table 8.—*Average number of live trees by diameter class and forest class; St. Vincent, 1984*

Diameter class	Forest class		
	Young secondary	Secondary	Primary
Cm	---------- *Trees per hectare* ----------		
5	1,788	967	1,687
10	763	334	422
15	113	86	38
20	49	47	49
25	26	22	24
30	5	14	16
35	5	7	11
40	4	8	20
45	2	5	14
50	*[1]	5	17
55	*	4	6
60	*	3	7
65	*	2	4
70	*	1	1
75+	2	3	8
Total[2]	2,758	1,506	2,324

[1]* = less than one tree per hectare.
[2]Column entries may not sum to totals due to rounding.

Table 9.—*Number of live trees by species and diameter class, ranked by basal area; young secondary forest, St. Vincent, 1984*

Use[1] code	Scientific name	Total basal area	Tree size class[2]			All size classes
			Sapling	Poletimber	Sawtimber	
		Square meters	*Thousand trees*			
2	*Inga vera*	6,147	430	95	16	541
2	*Licania ternatensis*	5,428	789	74	3	865
3	*Cyathea arborea*	4,729	574	34	.....	608
3	*Cecropia peltata*	4,069	72	78	9	159
3	*Myrcia deflexa*	3,780	287	57	.....	343
2	*Sloanea massoni*	3,238	502	94	.....	596
3	*Prestoea montana*	3,153	574	.....	.....	574
3	*Eugenia procera*	2,553	1,363	.....	.....	1,363
3	*Hedyosmum arborescens*	2,527	789	.....	.....	789
3	*Symplocos martinicensis*	2,337	143	72	.....	215
2	*Chimarrhis cymosa*	1,700	.....	.....	11	11
2	*Cordia sulcata*	1,513	413	.....	5	435
2	*Inga ingoides*	1,344	359	.....	.....	359
1	*Dacryodes excelsa*	1,275	.....	.....	2	2
2	*Sapium caribaeum*	1,275	.....	25	4	29
3	*Lonchocarpus violaceus*	1,275	.....	59	.....	59
....	*Pouteria multiflora*	1,202	143	11	*[3]	154
....	*Acanthaeaceae*	863	574	.....	.....	574
3	*Ochroma pyramidale*	850	.....	.....	4	4
2	*Nectandra coriacea*	726	143	9	.....	153
....	*Daphnopsis americana*	718	143	.....	.....	143
....	*Guettarda scabra*	702	359	.....	.....	359
2	*Citharexylum spinosum*	670	72	.....	*	72
....	*Ocotea leucoxylon*	579	287	.....	.....	287
3	*Ixora ferrea*	534	359	.....	.....	359
	14 other species	4,939	717	65	14	796
	All species[4]	58,125	9,107	673	67	9,847

[1]High-quality sawtimber = code 1; utility poletimber and sawtimber = code 2; currently unusable timber = code 3.

[2]Saplings are 2.5 to 12.5 cm d.b.h.; poletimber trees are 12.5 to 27.5 cm d.b.h.; sawtimber trees are larger than 27.5 cm d.b.h.

[3]* = Less than 500 trees.

[4]Column entries may not sum to totals due to rounding.

classes. Steep slopes, unstable soils, high rainfall, periodic storms, and volcanic eruptions create a very dynamic forest. Sample plots established randomly under these conditions reflect a great deal of this natural diversity.

Species Composition

Species composition varies considerably among the three timberland classes (tables 9, 10, 11). Although the classes represent three stages of a successional process, an orderly succession of species is not immediately apparent. Inventory sample plots were scattered over the island in different forest stands, so the data does not represent a series of observations of a changing forest, but rather a snapshot of current forests in different stages of development. Tropical species are seldom uniformly distributed over an area, and St. Vincent is no exception. Individual species tend to have a clustered distribution that enhances the stand and site variability associated with diverse stand origins, physiography, and disturbance.

Many of the species listed in the tables were sampled at only one location. It was not possible to install enough samples to intensively study individual species. Generally, the data on larger trees (poletimber and sawtimber) sampled with a prism are more accurate than the data on saplings. It follows that the species data for young secondary forests are least reliable, and data for the primary forest are most reliable. In the following discussion, only species that seem to have been reasonably well sampled are mentioned.

Young secondary forests are composed of pioneer saplings and poletimber such as *I. vera* and *Cecropia peltata*. Several species are common as saplings but absent from larger size classes. Scattered large trees are remnants of previous forests, including *Dacryodes excelsa, Chimarrhis cymosa,* and *Licania ternatensis.*

Table 10.—*Number of live trees by species and diameter class, ranked by basal area; secondary forest, St. Vincent, 1984*

Use[1] code	Scientific name	Total basal area	Tree size class[2]			All size classes
			Sapling	Poletimber	Sawtimber	
		Square meters	*Thousand trees*			
2	*Inga vera*	9,822	456	95	55	606
3	*Eugenia sintenisii*	5,037	326	71	10	407
3	*Prestoea montana*	4,736	326	104	.....	429
3	*Cecropia peltata*	4,663	586	26	15	628
2	*Ficus citrifolia*	4,246	.....	7	17	23
1	*Dacryodes excelsa*	3,474	.....	24	11	35
2	*Chimarrhis cymosa*	3,131	65	9	10	85
3	*Ficus obtusifolia*	2,702	.....	.....	11	11
1	*Guarea guidonia*	2,567	521	.....	.....	521
1	*Tabebuia pallida*	2,316	.....	.....	10	10
2	*Cordia sulcata*	2,301	521	.....	4	526
1	*Meliosma herbertii*	1,930	.....	36	5	41
3	*Artocarpus altilis*	1,544	.....	.....	8	8
2	*Sterculia caribaea*	1,493	195	77	.....	272
1	*Andira inermis*	1,195	65	24	6	96
....	*Rubiaceae*	1,050	456	.....	.....	456
2	*Nectandra coriacea*	802	130	.....	.....	130
2	*Citharexylum fruticosum*	772	.....	18	4	21
3	*Faramea occidentalis*	772	.....	44	.....	44
1	*Phoebe elongata*	772	.....	.....	3	3
2	*Sloanea caribaea*	772	.....	.....	3	3
1	*Freziera hirsuta*	772	.....	.....	3	3
	14 other species	5,735	1,172	37	14	1,224
	All species[3]	62,606	4,820	572	191	5,583

[1]High-quality sawtimber = code 1; utility poletimber and sawtimber = code 2; currently unusable timber = code 3.

[2]Saplings are 2.5 to 12.5 cm d.b.h.; poletimber trees are 12.5 to 27.5 cm d.b.h.; sawtimber trees are larger than 27.5 cm d.b.h.

[3]Column entries may not sum to totals due to rounding.

Secondary forests contain many of the same species, with pioneers reaching maturity and the longer-lived species beginning to form a canopy (table 10). *Inga vera* is clearly the dominant species, accounting for 16 percent of the basal area and 29 percent of all sawtimber trees. *Prestoea montana* and *C. peltata* have persisted and many have reached maturity. *Chimarrhis cymosa* and *Ficus citrifolia* are frequently observed with d.b.h. between 50 and 70 cm. Again, some species are present only as large residual trees from prior forest stands or old fields.

Primary forest composition is quite different from the composition of the younger successional forests (table 11). Short-lived pioneers and secondary species have been replaced or outgrown by overstory giants of many different species, and some new understory species adapted to the moist, shady environment beneath the canopy have appeared.

Dacryodes excelsa, L. ternatensis, Ormosia monosperma, and *Sloanea massoni* together account for 40 percent of the basal area and 33 percent of all sawtimber trees. Several species were encountered only as large sawtimber specimens with no evidence of reproduction under the canopy or in successional forest classes. Absent from the mature forest were several common successional species: *Inga vera, P. montana, Cecropia peltata, F. citrifolia,* and *Chimarrhis cymosa.*

For all classes of timberland combined, *I. vera* comprises the most basal area, followed by *L. ternatensis, D. excelsa,* and *Cecropia peltata.* The largest d.b.h. recorded was for a *S. massoni*, at 191.7 cm. The tallest tree was another *S. massoni,* at 48 m.

Timber Volume

Timber volume is the volume, inside the bark, of all sound wood, including bole and branch defects such as crook or large knots, of all tree sections with a minimum diameter of 10 cm and a minimum length of 1 m. This represents the wood volume removed from the forest for all forest products other than fuelwood. Growing-stock volume excludes the cull or rough sections and all of the wood in trees classified as rough or rotten due to excessive incidence of these defects. Growing-stock volume is the wood volume that the commercial logger would remove from the forest for

Table 11.—*Number of live trees by species and diameter class, ranked by basal area; primary forest, St. Vincent, 1984*

Use[1] code	Scientific name	Total basal area	Tree size class[2]			All size classes
			Sapling	Poletimber	Sawtimber	
		Square meters	*Thousand trees*			
1	*Dacryodes excelsa*	5,562	76	25	18	119
2	*Licania ternatensis*	5,517	1,683	22	9	1,713
1	*Ormosia monosperma*	5,024	76	.....	19	96
2	*Sloanea massoni*	4,080	.....	.....	10	10
2	*Talauma dodecaceptala*	3,173	.....	.....	11	11
....	*Rubiaceae*	2,821	76	30	9	116
2	*Sloanea caribaea*	2,764	76	.....	8	84
2	*Actinostemen caribeus*	2,720	.....	.....	14	14
3	*Symplocos martinicensis*	2,156	229	33	.....	263
1	*Micropholis chrysophylloides*	1,973	76	21	14	112
3	*Miconia virescens*	1,841	229	.....	.....	229
2	*Pithecellobium jupunda*	1,813	.....	.....	12	12
1	*Simaruba amara*	1,813	.....	.....	9	9
3	*Erythroxylon squamatum*	1,360	.....	28	4	32
3	*Cassipourea guianensis*	1,140	153	.....	1	154
3	*Ixora ferrea*	1,126	306	10	.....	316
2	*Canella winterana*	907	.....	12	1	13
3	*Eugenia sintenisii*	519	76	.....	1	78
....	*Meliosma herbertii*	507	76	.....	6	82
	10 other species	3,315	306	.....	23	329
	All species[3]	50,132	3,442	181	169	3,792

[1]High-quality sawtimber = code 1; utility poletimber and sawtimber = code 2; currently unusable timber = code 3.

[2]Saplings are 2.5 to 12.5 cm d.b.h.; poletimber trees are 12.5 to 27.5 cm d.b.h.; sawtimber trees are larger than 27.5 cm d.b.h.

[3]Column entries may not sum to totals due to rounding.

use as pulpwood, sawtimber, or veneer bolts. Sawtimber volume is the net volume of wood in all trees larger than 27.5 cm in d.b.h. that can be sawn into lumber. These trees must contain a saw log at least 22.5 cm in diameter outside bark and 3.5 m in length.

Timber volume in the young secondary forest averages 52.7 m^3/ha. The average rises to 98.6 m^3 in secondary forests and 251.3 m^3 in the primary forest. Although the majority of the volume is found in larger trees, all size classes show an increase in volume in the secondary and primary forest classes (fig. 8). Of most interest to the prospective logger is the volume in large sawtimber trees (d.b.h. larger than 47.5 cm).

Most of the usable volume in young secondary forests is found in the occasional large residual trees. This is best indicated by the sawtimber volume total, which averages 7.2 m^3/ha, mostly in *D. excelsa* and *L. ternatensis* (table 12). *Inga vera* and *C. peltata* account for more timber volume, but this is in smaller sawtimber and poletimber. *Inga vera* has some utilization potential for utility or construction grade products.

Inga vera is also the principal timber species in secondary forests (table 13). Sawtimber volume for all species averages 13.7 m^3/ha, with four species accounting for 72 percent of the total. Of these four, *D. excelsa* and *Chimarrhis cymosa* are present in large sawtimber sizes and would be the preferred harvest species.

Secondary forests are reasonably well stocked with timber; some individual stands carry as much as 44 m^3/ha of sawtimber. Factors that might limit the availability of this timber by making it uneconomical or impractical to harvest include accessibility, terrain

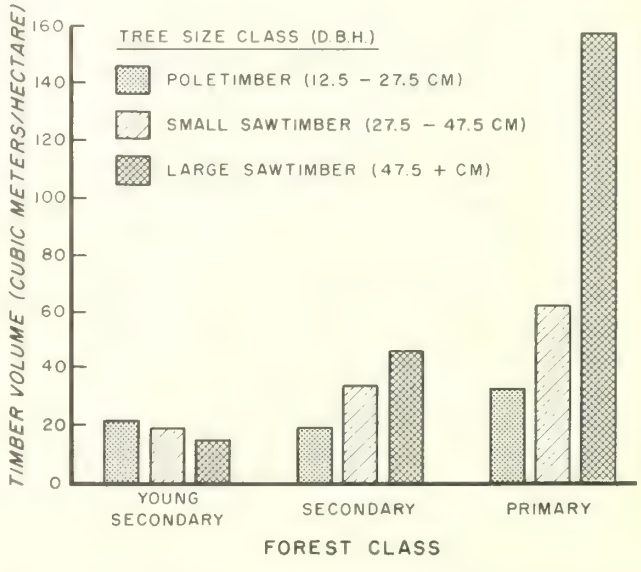

Figure 8.—*Average timber volume by forest class and tree size class; St. Vincent timberland.*

Table 12.—*Volume of timber, growing stock, and sawtimber by species and tree size class*[1]*; young secondary forest, St. Vincent, 1984*

Scientific name	Timber volume[2]			Growing-stock volume[3]			Sawtimber volume[4]
	Poletimber	Sawtimber	Total	Poletimber	Sawtimber	Total	Total
	Thousand cubic meters						
Inga vera	6.1	21.6	27.7	5.9	14.5	20.4	1.2
Cecropia peltata	15.9	8.6	24.5	15.8	5.0	20.8	1.4
Dacryodes excelsa	.....	17.3	17.3	.....	16.8	16.8	10.5
Licania ternatensis	5.6	10.5	16.1	5.6	9.2	14.8	5.4
Chimarrhis cymosa	.....	9.9	9.9	.....	6.6	6.6	2.1
Sapium caribaeum	4.8	4.3	9.1	4.3	3.0	7.4	.....
Cordia sulcata	.....	8.8	8.8	.....	6.7	6.7	.....
Pouteria multiflora	2.8	5.0	7.8	2.7	4.1	6.7	.....
Myrcia deflexa	6.5	.....	6.5	6.4	.....	6.4	.....
Cordia collococca	.....	6.4	6.4	.....	5.2	5.2	2.6
Ochroma pyramidale	.....	6.1	6.1	.....	5.1	5.0	2.2
Cyathea arborea	5.9	.....	5.9	.....	.....	.....	.....
Sloanea massoni	5.7	.....	5.7	5.7	.....	5.7	.....
Lonchocarpus violaceus	5.2	.....	5.2	5.1	.....	5.1	.....
Linociera caribaea	.....	4.7	4.7	.....	3.5	3.5	.....
Citharexylum spinosum	.....	3.8	3.8	.....	3.6	3.6	.....
Simaruba amara	3.8	.....	3.8	3.6	.....	3.6	.....
Meliosma herbertii	.....	3.7	3.7	.....	2.8	2.8	.....
Andira inermis	.....	3.4	3.4	.....	2.5	2.5	0.4
Symplocos martinicensis	3.1	.....	3.1	3.0	.....	3.0	.....
Nectandra coriacea	3.1	.....	3.1	3.0	.....	3.0	.....
5 other species	4.5	1.2	5.7	4.3	0.5	4.8	.....
All species[5]	72.9	115.2	188.1	65.4	89.1	154.5	25.8

[1]Poletimber trees are between 12.5 and 27.5 cm d.b.h., and sawtimber trees are greater than 27.5 cm d.b.h.

[2]Volume of all sound wood in all live trees to a minimum 10-cm diameter outside bark.

[3]Volume of sound wood (less sound cull volume) in growing-stock trees of potential commercial species to a minimum 10-cm diameter outside bark.

[4]Net volume of the saw log portion of sawtimber trees of potential commercial species, calculated according to the International rule.

[5]Column entries may not sum to totals due to rounding.

roughness and slope, and the ecological values of the forest. Much of the secondary forest is located in very rugged, uninhabited terrain that does not contain roads or even good trails. The forests are probably the result of natural rather than human disturbance. Physical difficulties limit the opportunities for log extraction. Of additional concern is the ecological value of these secondary forests and the role they may play as seed sources and habitats for many plant and animal species. The parcels are often located adjacent to or within mature timber stands as a part of a single, dynamic forest ecosystem.

The primary forest carries the high volumes usually reported for the tropical moist forest (table 14). Many different species are represented by large mature individuals that contain as much as 20 m^3 of timber. Sawtimber volume averages 65 m^3/ha, with high quality timber accounting for 44 percent of the total. *Dacryodes excelsa, O. monosperma, Actinostemen caribeus,* and *Talauma dodecaceptala* together comprise 59 percent of all sawtimber.

The dense timber stands are unlikely to be harvested soon due to the extremely rugged terrain and lack of roads or easy access. The primary forest, because of its limited distribution in the Antilles and the uniqueness of the vegetation on each island, may be the most valuable natural resource of St. Vincent. Besides helping to maintain the island ecosystem and sustain water supplies in the water catchments, the natural forests have the potential to attract tourists and provide habitat for interesting and endangered wildlife species. Since the mature tropical forest may take hundreds of years to fully regenerate, this resource should be managed with the greatest care.

The majority of the timber in young secondary and secondary forests is contained in rough cull trees (table 15). Successional species have a tendency to become crooked and limby because they grow under uncrowded conditions in early years. Some of the large, residual trees on abandoned agricultural land were open-grown as well.

In contrast, two-thirds of the timber in the primary forest is found in growing-stock trees. These trees have survived competition by growing tall and straight in early years and shedding lower branches. Because of the size of these trees, 20 percent of the

Table 13.—*Volume of timber, growing stock, and sawtimber by species and tree size class*[1]*; secondary forest, St. Vincent, 1984*

Scientific name	Timber volume[2]			Growing-stock volume[3]			Sawtimber volume[4]
	Poletimber	Sawtimber	Total	Poletimber	Sawtimber	Total	Total
	Thousand cubic meters						
Inga vera	17.3	55.9	73.3	14.2	40.5	54.7	10.1
Dacryodes excelsa	5.1	30.2	35.2	5.0	26.9	31.9	11.5
Ficus citrifolia	1.6	32.0	33.6	1.5	19.0	20.6	.....
Chimarrhis cymosa	1.6	25.5	27.1	1.6	18.4	20.0	8.7
Cecropia peltata	3.5	22.0	25.6	3.5	16.1	19.6	6.2
Ficus obtusifolia	.....	24.6	24.6	.....	16.6	16.6	2.5
Tabebuia pallida	.....	18.6	18.6	.....	12.8	12.8	.....
Eugenia sintenisii	6.4	10.3	16.7	5.8	7.6	13.3	1.1
Artocarpus altilis	.....	12.9	12.9	.....	11.1	11.1	3.9
Prestoea montana	11.0	.....	11.0	.....	.....	.....	.....
Cordia sulcata	.....	10.4	10.4	.....	6.9	6.9	.....
Sapium caribaeum	.....	9.1	9.1	.....	7.1	7.1	3.6
Freziera hirsuta	.....	7.8	7.8	.....	6.2	6.2	.....
Andira inermis	4.9	2.5	7.4	4.7	2.3	7.0	.....
Sloanea caribaea	.....	6.7	6.7	.....	4.9	4.9	.....
Phoebe elongata	.....	5.6	5.6	.....	4.0	4.0	.....
Sterculia caribaea	4.9	.....	4.9	4.9	.....	5.0	.....
Citharexylum fruticosum	1.2	2.9	4.1	0.6	1.9	2.5	.....
Actinostemen caribeus	.....	4.0	4.0	.....	2.8	2.8	0.8
Faramea occidentalis	3.8	.....	3.8	3.7	.....	3.7	.....
6 other species	10.1	13.2	23.3	5.8	10.2	16.1	2.3
All species[5]	71.4	294.1	365.5	51.3	215.4	266.7	50.6

[1]Poletimber trees are between 12.5 and 27.5 cm d.b.h., and sawtimber trees are greater than 27.5 cm d.b.h.
[2]Volume of all sound wood in all live trees to a minimum 10-cm diameter outside bark.
[3]Volume of sound wood (less sound cull volume) in growing-stock trees of potential commercial species to a minimum 10-cm diameter outside bark.
[4]Net volume of the saw log portion of sawtimber trees of potential commercial species, calculated according to the International rule.
[5]Column entries may not sum to totals due to rounding.

timber is contained in branches, forks, and large sections of the bole above the saw log.

For all timberland classes combined, *D. excelsa* has the highest growing-stock volume, followed by two successional species, *I. vera* and *C. peltata* (fig. 9). The other common species are generally located in or near the primary forest.

Dacryodes excelsa clearly has the highest grade of sawtimber, with 64 percent of the wood in grade 1 logs (table 16). For all other species the proportion of sawtimber in grade 1 logs is 19 percent, with 50 percent in grade 2 logs and 30 percent in grade 3 logs.

Management Opportunities for Natural Forests

With population growth, domestic water demands will increase. Likewise, future expansion of tourism or the introduction of small industry on St. Vincent will create greater demands for water. The continuous supply of good quality water throughout the year is dependent on maintaining forest cover on government-owned lands in the interior. These lands should be protected against further intrusion, and plantations should be established on steep slopes to conserve water and to reduce soil erosion and reservoir sedimentation.

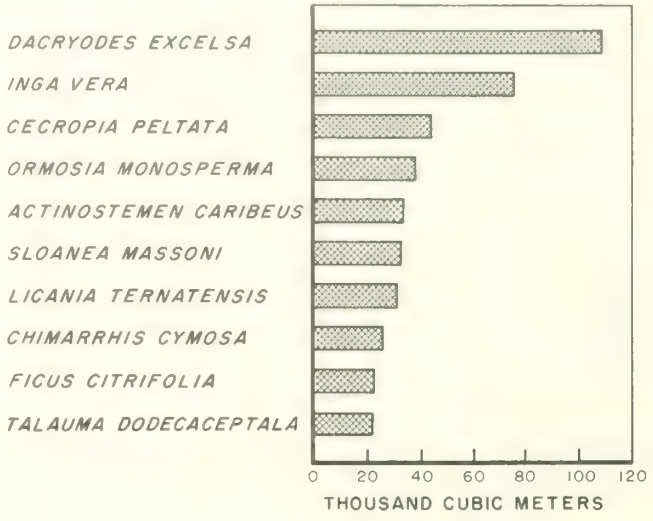

Figure 9.—*Growing-stock volume of 10 common tree species; St. Vincent timberland.*

Table 14.—*Volume of timber, growing stock, and sawtimber by species and tree size class[1]; primary forest, St. Vincent, 1984*

Scientific name	Timber volume[2]			Growing-stock volume[3]			Sawtimber volume[4]
	Poletimber	Sawtimber	Total	Poletimber	Sawtimber	Total	Total
	Thousand cubic meters						
Dacryodes excelsa	6.5	59.5	66.0	6.5	52.8	59.3	25.5
Ormosia monosperma	.....	51.1	51.1	.....	34.4	34.4	10.6
Sloanea massoni	.....	40.0	40.0	.....	26.7	26.7	4.2
Actinostemen caribeus	.....	37.1	37.1	.....	30.2	30.2	16.2
Talauma dodecaceptala	.....	30.0	30.0	.....	22.9	22.9	10.0
Sloanea caribaea	.....	26.3	26.3	.....	8.9	8.9	.....
Pithecellobium jupunda	.....	19.2	19.2	.....	15.3	15.3	5.2
Licania ternatensis	2.1	17.1	19.2	2.0	13.4	15.4	7.9
Rubiaceae (sp. unknown)	3.1	15.8	18.9	3.1	12.6	15.7	2.3
Simaruba amara	.....	18.8	18.8	.....	16.1	16.1	8.4
Sapium caribaeum	.....	11.0	11.0	.....	8.5	8.5	5.1
Micropholis chrysophylloides	2.4	8.4	10.8	2.5	6.8	9.2	2.0
Erythroxylon squamatum	6.1	3.2	9.3	5.9	2.3	8.2	.....
Symplocos martinicensis	8.0	.....	8.0	7.9	.....	7.9	.....
Guapira fragrans	.....	7.3	7.3	.....	6.0	6.0	3.1
Meliosma herbertii	.....	5.9	5.9	.....	4.2	4.2	2.5
Canella winterana	2.3	3.2	5.5	1.8	2.8	4.6	.....
Guarea guidonia	.....	5.3	5.3	.....	4.4	4.4	1.6
Linociera caribaea	.....	5.0	5.0	.....	3.6	3.6	1.2
Cecropia peltata	.....	4.3	4.3	.....	3.2	3.2	.....
4 other species	2.4	8.9	11.3	2.4	7.4	9.7	.....
All species[5]	32.9	377.3	410.2	32.1	282.4	314.4	105.7

[1]Poletimber trees are between 12.5 and 27.5 cm d.b.h., and sawtimber trees are greater than 27.5 cm d.b.h.

[2]Volume of all sound wood in all live trees to a minimum 10-cm diameter outside bark.

[3]Volume of sound wood (less sound cull volume) in growing-stock trees of potential commercial species to a minimum 10-cm diameter outside bark.

[4]Net volume of the saw log portion of sawtimber trees of potential commercial species, calculated according to the International rule.

[5]Column entries may not sum to totals due to rounding.

Table 15.—*Volume of timber by class of timber and forest class; St. Vincent, 1984*

Class of timber	Forest class		
	Young secondary	Secondary	Primary
	Cubic meters per hectare		
Growing-stock trees			
Sawtimber trees			
Saw log portion of bole	12.0	25.0	112.2
Upper stem of bole	1.9	7.3	22.4
Branches and forks	2.8	7.6	21.9
Sound cull	0.9	1.5	12.7
Timber volume	17.6	41.4	169.2
Poletimber trees			
Bole volume	6.2	5.8	15.2
Branches and forks	.....	.....	.....
Sound cull	0.2	0.7	.....
Timber volume	6.4	6.5	15.2
Rough and rotten trees			
Bole volume	23.1	33.9	42.9
Branches and forks	2.8	6.8	7.3
Sound cull	2.8	10.0	16.8
Timber volume	28.7	50.7	67.0
All timber[1]	52.7	98.6	251.4

[1]Column entries may not sum to totals due to rounding.

Table 16.—*Volume of sawtimber by species and log grade; St. Vincent, 1984*

Scientific name	Log grade[1]				All grades
	1	2	3	4	
	---- *Thousand cubic meters* ----				
Dacryodes excelsa	30.4	8.9	8.2	...	47.5
Actinostemen caribeus	...	16.2	0.8	...	17.0
Licania ternatensis	3.1	7.9	2.2	...	13.2
Ormosia monosperma	7.0	4.9	...	...	11.9
Inga vera	2.0	2.5	6.8	...	11.3
Chimarrhis cymosa	...	10.8	...	...	10.8
Talauma dodecaceptala	3.8	4.8	1.3	...	10.0
Sapium caribaeum	5.1	3.6	...	...	8.7
Simaruba amara	2.0	2.0	4.4	...	8.4
Cecropia peltata	...	4.1	3.6	...	7.7
Pithecellobium jupunda	...	1.5	3.7	...	5.2
Sloanea massoni	2.7	...	1.4	...	4.1
Artocarpus altilis	...	...	3.9	...	3.9
Meliosma herbertii	...	...	3.4	...	3.4
Guapira fragrans	...	3.1	...	...	3.1
Cordia collococca	...	2.6	...	...	2.6
Ficus obtusifolia	...	1.8	0.6	...	2.5
Rubiaceae (sp. unknown)	...	1.2	...	1.1	2.3
Ochroma pyramidale	...	...	2.2	...	2.2
Micropholis chrysophylloides	...	...	2.0	...	2.0
4 other species	...	...	4.4	...	4.4
All species	56.1	76.0	48.9	1.1	182.1

[1]Graded by hardwood log grade standards used in Southern U.S.

The minimum stocking standard for Puerto Rico is 250 saplings or 100 poletimber-size trees per hectare of desirable species to assure reasonable stocking of a timber stand at maturity. Young secondary forests in St. Vincent contain 10 times this standard of saplings and twice this standard of poletimber trees, but the vast majority are classed as rough cull trees and would not be good candidates for future crop trees (table 17). This proportion is much higher than the 45 percent found in young secondary forests of Puerto Rico. Such poor stocking, regardless of species, indicates that management of natural regeneration at this early stage of stand development would be premature. Replacement of young secondary forests with plantation species could be accomplished easily by clearing the small trees and other inhibiting vegetation.

Stocking improves somewhat for secondary forests that average 281 saplings and 45 poletimber growing-stock trees (table 17). There would be some stands with sufficient growing stock that could be improved by girdling or injecting rough cull trees and undesirable species. Species to favor because of wood quality would include *I. vera, F. citrifolia, D. excelsa, Chimarrhis cymosa, Tabebuia pallida, Guarea guidonia, Cordia sulcata, Meliosma herbertii, Sterculia caribaea, Andira inermis,* and *Nectandra coriaceae. Eugenia sintenisii* and *Cecropia peltata* should be removed or deadened, while some understory species such as *P. montana* would not compete in the long run with the larger species favored for timber production. These could be left untreated.

The much better stocking of growing-stock trees in the primary forest indicates that natural selection processes would eventually favor the larger timber species. Growing-stock basal area averages 64 percent of all stocking in the primary forest, compared with 34 percent in secondary and 16 percent in the young secondary classes (table 18). Although more

Table 17.—*Average number of trees by size class, tree class, and forest class; St. Vincent, 1984*

Size class and tree class	Forest class			All classes
	Young secondary	Secondary	Primary	
	---------- *Trees per hectare* ----------			
Saplings				
Growing stock	80	281	1,125	355
Rough and rotten	2,471	1,019	984	1,595
Total	2,551	1,301	2,109	1,950
Poletimber trees				
Growing stock	28	45	81	45
Rough and rotten	161	109	29	115
Total	188	154	111	160
Sawtimber trees				
Growing stock	8	25	77	27
Rough and rotten	11	27	27	20
Total	19	51	104	48
All size classes				
Growing stock	116	351	1,283	428
Rough and rotten	2,642	1,156	1,041	1,730
Total[1]	2,758	1,506	2,323	2,158

[1]Column entries may not sum to totals due to rounding.

Table 18.—*Average basal area by size class, tree class, and forest class; St. Vincent, 1984*

Size class and tree class	Forest class			All classes
	Young secondary	Secondary	Primary	
	------- *Square meters per hectare* -------			
Saplings				
Growing stock	0.3	0.7	2.8	0.9
Rough and rotten	8.2	3.6	2.9	4.3
Total	8.4	4.3	5.7	6.2
Poletimber trees				
Growing stock	1.0	1.1	2.5	1.3
Rough and rotten	3.6	2.7	1.1	2.8
Total	4.5	3.8	3.6	4.1
Sawtimber trees				
Growing stock	1.4	3.9	14.4	4.8
Rough and rotten	1.9	4.9	6.9	4.1
Total	3.3	8.8	21.4	8.9
All size classes				
Growing stock	2.6	5.7	19.8	7.1
Rough and rotten	13.6	11.2	11.0	12.1
Total[1]	16.3	16.9	30.7	19.2

[1]Column entries may not sum to totals due to rounding.

than half the saplings in the primary forest are classed as growing stock, many are suppressed and would probably not respond to release cutting.

In summary, the best prospects for management of natural forests to improve timber species' stocking would be in secondary forest stands with adequate stocking of desirable saplings and poletimber. Implementation of natural forest management requires a detailed survey of the species composition of a particular stand and some experience with how the individual species might respond to release. In the absence of additional applied research studies, it is not recommended that natural forest management be attempted in the forests of St. Vincent on the basis of this survey alone.

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APPENDIX

RELIABILITY OF THE DATA

Reliability of the estimates may be affected by two types of errors. The first type stems from the use of a sample to estimate the whole and from variability of the items being sampled. This is termed sampling error; it is susceptible to a mathematical evaluation of the probability of error. The second type—often referred to as reporting or estimating error—derives from mistakes in measurement, judgment, or recording and from limitations of methods or equipment. This type of error is held to a minimum by proper training, supervision, and precision.

Statistical analysis of the data indicates a sampling error of plus or minus 3.6 percent for forest area. Timber volume sampling error was estimated to be 19.1 percent. As these totals are broken down by species, tree size, or other classifications, the possibility for error increases and is greatest for the smallest subdivisions.

DEFINITIONS

Basal Area.—The area in square meters of the cross section at breast height of a single tree or of all the trees in a stand, expressed as square meters per hectare.

D.b.h. (diameter at breast height).—Tree diameter in centimeters, outside bark, measured at 1.3 m above ground.

Dry Scrub Forest.—Fine woody vegetation generally less than 10 m tall at maturity, found under dry conditions typical of the Subtropical Dry Life Zone and certain serpentine and limestone soils.

Dwarf Forest.—Also known as cloud forest or elfin woodland, the dwarf forest is found on the summits of the highest mountains and is characterized by densely packed, knarled trees less than 7 m tall.

Forest Land.—Land at least 10 percent stocked by forest trees of any size, or formerly having had such tree cover and not currently developed for nonforest use. The minimum area for classification of forest

land is 0.5 ha, and the minimum width for forest strips is 35 m. Unimproved roads and trails, streams, and clearings in forest areas are classed as forest if less than 35 m in width.

Growing-Stock Trees.—Sawtimber trees, poletimber trees, saplings, and seedlings; that is, all live trees except rough and rotten trees.

Nonstocked Land.—Commercial forest land less than 10 percent stocked with growing-stock trees. This includes areas covered by inhibiting vegetation (brush, vines, ferns, etc.) classed as forest land.

Other Forest Land.—Forest land incapable of yielding timber crops because of adverse site conditions, forest land withdrawn from timber utilization through statute or administrative regulation, or forest land with higher priority use.

Palm Forest.—Nearly pure stands of *Prestoea montana* that form in upper mountain regions.

Poletimber Trees.—Growing-stock trees, 12.5 to 22.5 cm in d.b.h. for softwoods and 12.5 to 27.5 cm for hardwoods, of good form and vigor.

Primary Forest.—Relatively undisturbed, mature, wet forest composed of mixed tree sizes. The canopy is generally higher than 7 m.

Rough and Rotten Trees.—Live trees that are unmerchantable for saw logs now or in the future because of defect or rot.

Saplings.—Growing-stock trees, 2.5 to 12.5 cm in d.b.h., and of good form and vigor.

Sawtimber Trees.—Growing-stock trees, 22.5 cm and larger in d.b.h. for softwoods and 27.5 cm and larger for hardwoods, containing at least one 3.5-m saw log.

Secondary Forest.—Forest resulting from the abandonment of cropland or pasture and forest resulting from the regeneration of previously cutover or disturbed forest land.

Timberland.—Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization.

Volume of Growing Stock.—Volume of sound wood (less cull volume) in the bole and branches of sawtimber and poletimber trees from the stump to a minimum 10-cm diameter outside bark or to the point past which a 1-m section meeting minimum qualifications can no longer be measured because of limbs or other cull.

Volume of Sawtimber.—Net volume of the saw log portion of sawtimber trees in cubic meters, calculated according to the International rule, 0.635 cm (1/4 inch) kerf.

Volume of Timber.—Volume of all sound wood (including sound cull) in the bole and branches of growing stock, rough, rotten, and salvable dead trees 12.5 cm and larger in d.b.h., from stump to a minimum 10 cm diameter outside bark. The minimum length of any section included is 1 meter.

Young Secondary Forest.—Secondary forest with most trees less than 10 years old.

Tree Species Tallied in St. Vincent, 1984

Scientific name	St. Vincent common name
Acanthaeaceae (sp. unknown)	
Actinostemen caribeus Griseb.	
Andira inermis (W. Wright) H.B.K.	Black plum, Jumbie mango
Artocarpus altilis (Parkinson) Fosberg	Breadfruit
Calophyllum antillanum Britton	Galba
Canella winterana (L.) Gaertn.	Wild cinnamon
Cassipourea guianensis Aubl.	
Cecropia peltata L.	Trumpet tree
Chimarrhis cymosa Jacq.	Waterwood
Citharexylum fruticosum L.	Fiddlewood
Citharexylum spinosum L.	Bastard fiddlewood
Cocos nucifera L.	Coconut
Conomorpha peruviana A.D.C.	
Cordia alliodora (Ruiz & Pav.) Oken	
Cordia collococca L.	Red manjack
Cordia sulcata DC.	White manjack
Croton populifolius Lam.	Black siege
Cyathea arborea (L.) J. E. Smith	Tree fern, jamen joe
Cyrilla racemiflora L.	Bloodwood

Tree Species Tallied in St. Vincent, 1984—Continued

Scientific name	St. Vincent common name
Dacryodes excelsa Vahl	Gommier
Daphnopsis americana (Mill.) J. R. Johnston	Local mahoe
Erythroxylon squamatum Sw.	
Eugenia procera (Sw.) Poir.	
Eugenia sintenisii Kiaersk.	Bashi guava
Faramea occidentalis (L.) A. Rich.	Wild coffee
Ficus citrifolia Vahl	Wild fig
Ficus obtusifolia H.B.K.	Fig
Freziera hirsuta Sm.	Gunstock
Guapira fragrans (Dum.-Cours.) Standley	Mapoo, loblolly
Guarea guidonia (L.) Sleumer	Black plum
Guettarda scabra (L.) Vent.	
Hedyosmum arborescens Sw.	
Hibiscus elatus Sw.	Blue mahoe
Inga ingoides (Rich) Willd.	Spanish ash
Inga vera Willd.	Spanish ash
Ixora ferrea (Jacq.) Benth.	Wild coffee
Licania ternatensis (Hook.) F.	Bois job
Linociera caribaea (Jacq.) Knobl.	Mastic
Lonchocarpus violaceus H.B.K.	Greenhart
Mangifera indica L.	Mango
Manilkara bidentata (A. DC.) Chev.	Bulletwood, balata
Meliosma herbertii Rolfe	Wild cocoa
Miconia virescens (Vahl.) Triana	Torchwood
Miconia elongata Vahl.	Candlewood
Micropholis chrysophylloides Pierre	Wild star apple
Myrcia deflexa (Poir.) DC.	Wild plumrose
Nectandra coriacea (Sw.) Griseb.	Sweetwood
Ochroma pyramidale Cav. Urban	Balsa, bafal
Ocotea leucoxylon (Sw.) Mez	Sweetwood
Ormosia monosperma (Sw.) Urb.	Sarinette
Phoebe elongata (Vahl) Nees	Sweetwood
Pinus caribaea Morelet	Pine
Pithecellobium jupunda (Willd.) Urb.	Wild tamarind
Pouteria multiflora (A. DC.) Eyma	Penny piece
Prestoea montana (R. Grah.) Nichols.	Palm
Rubiaceae (sp. unknown)	
Sapium caribaeum	Burn lime
Simaruba amara Aubl.	Board wood
Sloanea caribaea Kr. and Urb.	Santinay
Sloanea massoni Sw.	Boo wood
Sterculia caribaea R. Br.	Mahoe
Swietenia macrophylla King	Mahogany
Swietenia mahogoni Jacq.	Mahogany
Symplocos martinicensis Jacq.	Sweet leaf
Tabebuia pallida (DC.) Britton	White cedar
Talauma dodecaceptala (Lam.) Urb.	Wild breadfruit, wild almond

Metric Inventory Standards

Item	Metric standard
Prism size	BAF 2.5
Grid spacing	3 km
Cluster point spacing	25 m
Fixed plot size	40 m^2 (r=3.6 m)
	15 m^2 (r=2.2 m)
Breast height	1.3 m
Stump height	30 cm
Diameter classes	5 cm=2.5 to 7.5 cm d.b.h.
	10 cm=7.5 to 12.5 cm d.b.h.
	15 cm=12.5 to 17.5 cm d.b.h.
	20 cm=17.5 to 22.5 cm d.b.h. etc.
Tree size classes	
Sapling	2.5 to 12.5 cm d.b.h.
Poletimber (hardwood)	12.5 to 27.5 cm d.b.h.
Sawtimber (hardwood)	27.5 cm+d.b.h.
Sawtimber (softwood)	22.5 cm+d.b.h.
Minimum top d.o.b.	
Cubic volume	10 cm
Hardwood saw log	22.5 cm
Softwood saw log	17.5 cm
Sapling	2.5 cm
Minimum d.i.b. saw log	
Hardwood	20 cm
Softwood	15 cm
Minimum length	
Cubic section	1 m
Saw log	2.5 m
Sawtimber tree	3.5 m saw log

Birdsey, Richard A.; Weaver, Peter L.; Nicholls, Calvin F. The forest resources of St. Vincent, West Indies. Res. Pap. SO-229. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1986. 25 p.

Presents the principal findings of a 1984 forest inventory of St. Vincent, one of the islands of the West Indies. Data covers plantations and natural forests. Plantation species include *Pinus caribaea, Swietenia macrophylla,* and *Hibiscus elatus.* Natural forest vegetation covers 38 percent of the land surface and consists of primary rain forest, secondary forest, palm forest, dwarf forest, and dry forest.

Additional keywords: timber volume, forest area, tropical forest management, Caribbean forests, island ecosystems.

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Impacts of Changes in the Commercial Forest Land Base on the Long-Term Pine Timber Supply Potential in Louisiana

James E. Hotvedt and Charles E. Thomas

CONTENTS

INTRODUCTION 1
Timber Demand-Supply Situation 1
Timber Supply Potential 1
Nation 1
South 2
Louisiana 2
Louisiana Timber Supply Model 3
DEVELOPMENT OF THE LOUISIANA SOFTWOOD TIMBER SUPPLY MODEL 3
Timber Supply Model 3
Management Levels and Regimes 5
Timber Yields 6
Plantations 6
Natural Stands 7
Custodial Stands 7
Management Costs 8
Timber Demand 11
RESULTS 11
Base 11
Double Interest Rates 12
Custodial Management Restrictions 13
Changes in the Commercial Timberland Base 13
Upland Hardwood Sites Excluded 15
POLICY IMPLICATIONS 15
SUMMARY AND DISCUSSION 16
LITERATURE CITED 17

Impacts of Changes in the Commercial Forest Land Base on the Long-Term Pine Timber Supply Potential in Louisiana

James E. Hotvedt and Charles E. Thomas

INTRODUCTION

Timber Demand-Supply Situation

Projected demands for timber in the future are substantial (USDA Forest Service 1982). For example, the demand for all roundwood in 2030 has been projected to more than double consumption of 1976, from 13.4 billion cubic feet in 1976 to 22.7 billion in 2000 and 28.3 billion in 2030. Most projected increase in demand is for roundwood pulpwood which will account for approximately 46 percent of the total in 2030, in contrast to only a third of consumption in 1976.

The domestic timber resource in most regions can support larger timber harvests for satisfying future demands (USDA Forest Service 1982). According to the Forest Service, the projected volume of roundwood available for harvest, assuming that commercial timberland owners continue to respond to price and inventory changes and to manage their timber stands much as they have in the recent past, could increase from 12.8 billion cubic feet in 1976 to 21.2 billion cubic feet in 2030, an increase of 66 percent. Approximately 2.8 billion cubic feet of the increase would come from softwoods and 5.6 billion from hardwoods.

The South is expected to produce much of the increased supply (USDA Forest Service 1982). For example, projected sawtimber supplies from the Pacific Northwest are expected to drop, but Southern supplies are expected to increase from 18.0 to 27.3 billion board feet, or 52 percent.

Despite these potential increases, demand is expected to exceed supply at current price levels in the future, particularly demand for softwoods (USDA Forest Service 1982). Projected demands for softwoods from domestic forests increase from an actual consumption of 9.2 billion cubic feet in 1976 to 13.8 billion cubic feet by year 2000 and 15.7 billion by 2030. However, projected softwood harvests total only 11.1 billion cubic feet in 2000 and 12.3 billion by 2030. Thus, a shortfall of 3.4 billion cubic feet, or 22 percent of projected demand, could be expected by year 2030.

Because of the imbalances between projected demands and supplies, relative timber prices can be expected to rise substantially higher than the price levels assumed in the base level projections prepared by the Forest Service (1982). In the South, softwood stumpage prices are expected to increase relative to other regions; measured in 1967 dollars and net of inflation or deflation, they are expected to rise at an annual rate of 2.5 percent between 1976 and 2030.

Real timber prices are expected to increase in the future, even under reduced demand and more liberal supply assumptions (Adams and Haynes 1985). Haynes and Adams (1985) departed from the set of "traditional" assumptions employed by the USDA Forest Service (1982) in recent timber demand-supply market analyses and conducted 15 simulations to examine the effects of alternative assumptions on the timber situation in the United States. Generally, they found that the demand for softwood continued to grow over the range of futures examined and that real increases in stumpage prices continued for most species and sizes, particularly softwood sawtimber and high quality hardwood sawtimber.

Can the country meet the rising demand for forest products? Must prices increase at a faster rate than inflation to induce increased supplies and reduced demands? What impact would rising prices have on the economy? Do the commercial timberlands of the nation have the potential productive capacity to meet future levels of demand at current price levels?

Timber Supply Potential

Nation.—In fact, the productive potential of the nation's forests is not being met. Its timberlands have the physical potential to produce much larger quantities of timber for satisfying future demands (USDA Forest Service 1982). In 1976, average net annual timber growth per acre on all ownerships was only about three-fifths of that attainable in fully stocked natural stands (USDA Forest Service 1982). In the South, the ratio was closer to three-fourths.

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Rising relative timber prices can be abated if the productive potential of the nation's forest is realized. However, this can only be achieved with higher levels of management intensity. Timberlands must be adequately regenerated to desirable species following harvest. In the South, neglect of regeneration to desirable species has resulted in changed forest types (USDA Forest Service 1982). The area in southern pine types and oak-pine types has been declining while the area in the oak-hickory type has been increasing. Farmers and other private landowners, who control 58 percent of the commercial timberland in the nation and 71 percent of the commercial timberland in the South, are primarily responsible due to the lack of provisions for adequate regeneration of pines following harvests on their timberlands.

Opportunities exist for improving productivity and increasing long-term timber supplies while yielding at least a 4 percent real rate of return or more on the investment (USDA Forest Service 1982). Intensifying management is potentially possible on 168 million acres of commercial timberland, some 35 percent of the nation's total. Net annual timber growth could be increased by as much as 12.9 billion cubic feet, approximately the total timber harvest in 1976 and about three-fifths of the total net annual growth in that year. According to the Forest Service (1982), reforestation or type conversion of existing stands represent the greatest economic opportunity on about three-quarters of the area. Most of the opportunities for increasing timber supplies are on farmer and other private ownership lands.

South.—Most of the acres on which management opportunities exist are in the South (USDA Forest Service 1982). About two-fifths of the country's commercial timberlands are in this region. It provides nearly half of the wood used in the pulp industry, almost a third of that used in the lumber industry, and about two-fifths of that consumed in the veneer and plywood industry. Further, most expansion in the forest products industry is likely to be based on the timber resources of this region.

Timber harvests in the South have been rising rapidly and are expected to continue doing so. For example, harvests of softwood roundwood increased from 2.7 to 4.2 billion cubic feet from 1962 to 1976; the projection increases to 6.2 billion cubic feet by 2030 (USDA Forest Service 1982). About three-fifths of the softwood harvests in 1976 came from farmer and other private ownerships.

Expansion of the forest products industry in the South could be limited because of the failure to adequately regenerate pine stands. Less than half of the commercial timberland acreage in the South capable of growing pine was occupied by pine trees in 1974 (USDA Forest Service 1982). Indeed, between 1970 and 1976, pine acreage declined by more than 4 million acres. This conversion to oak-pine or hardwood forest types resulted from the lack of provisions for regeneration after harvest of pine stands on land owned by the farmer and other private ownership class.

Over three-fifths of the commercial timberland in the South offers opportunities for increasing timber supplies; over 75 percent of these opportunities consists of some form of stand conversion or reforestation (USDA Forest Service 1982). These opportunities would yield a rate of return ranging from 10 to 26 percent (after inflation) and almost double the net annual growth in the area for 1976. Again, these opportunities primarily occur on lands owned by farmers and other private ownerships.

The increased dependence on the South for softwood timber resources is well recognized, and dependence on the farmer and other private ownerships for increasing softwood timber supplies is generally acknowledged. However, this ownership class is often reluctant to invest in management practices such as site preparation, planting, and timber stand improvement. Consequently, the softwood timber resource may not be maintained or increased in the future.

Louisiana.—According to a soon to be published Forest Service survey, the commercial timberland base in Louisiana comprises approximately 14.1 million acres of forest land, or about 55 percent of the total land base in the state. About 11 percent of the commercial timberland is in pine plantations, 25 percent in natural pine forest types, 14 percent in mixed pine-hardwood forest types, 34 percent in bottomland hardwood forest types, and 16 percent in upland hardwood forest types. The pine, mixed pine-hardwood, and upland hardwood forest types (about 66 percent of the total forest land base) are the types considered in this study.

Of the approximately 9.2 million acres studied, about 53 percent is owned by the nonindustrial private forest (NIPF) landowner group, 39 percent is owned by industry, and the remaining 9 percent is controlled by public agencies (table 1). A majority of the commercial timberland is in the medium site classes (those capable of producing 50–120 cubic feet per acre per year) and the remainder is largely in the higher site classes (those capable of producing at least 120 cubic feet per acre per year). About one-quarter of the timberland of interest is in upland hardwood forest types, the remainder primarily in pine and mixed pine-hardwood types.

Annual softwood timber production in the period 1980-84 in Louisiana has ranged from 762.20 to 1,048.15 million board feet of sawtimber and from 2.76 to 3.03 million cords of pulpwood (table 2). Total revenue generated from timber harvesting has ranged from $169.8 million in 1982 to $234.6 million in 1984. Average annual total softwood production in

Table 1.—*Commercial forest land area in Louisiana in pine or convertible to pine, by ownership, by cover type, by site productivity class, 1985*

Site Class[1]	Public			Industry[2]			Nonindustrial private			Total
	Pine	Oak-pine	Upland hdwd	Pine	Oak-pine	Upland hdwd	Pine	Oak-pine	Upland hdwd	
1	171.3	58.9	54.7	914.3	379.3	275.9	1286.0	486.3	491.4	4118.1
2	303.3	104.0	68.3	1118.4	364.5	500.3	1186.8	568.8	795.4	5009.8
3	12.3	.....	.....	23.9	.....	.....	35.9	.....	23.4	95.5
Total	486.9	162.9	123.0	2056.6	743.8	776.2	2508.7	1055.1	1310.2	9223.4

[1] Site class: 1 > 120 cubic feet/acre/year
2 50–120 cubic feet/acre/year
3 20–50 cubic feet/acre/year

[2] Includes fee and leased lands.

Table 2.—*Softwood timber production and income from timber sales in Louisiana, 1980–84*[1]

Year	Production		Revenues		
	Sawtimber	Pulpwood	Sawtimber	Pulpwood	Total
	Mil bd ft	*Mil cds*	------- *Million dollars* ------		
1980	814.42	2.76	172.7	28.1	200.8
1981	782.23	2.83	175.2	36.8	212.0
1982	762.20	2.98	125.0	44.8	169.8
1983	1,048.15	2.87	184.5	48.9	233.4
1984	973.38	3.03	183.0	51.6	234.6

[1]Source: Louisiana Department of Natural Resources, Office of Forestry, Timber and Pulpwood Production in Louisiana (Annual). Baton Rouge, LA.

the period was about 469.6 million cubic feet, while the associated weighted average stumpage price was $.394 per cubic foot, or $394 per thousand cubic feet.

In light of the potential timber supply shortage in the nation, what role might the state of Louisiana have in meeting the nation's future timber demand? What might that impact be on future timber prices in the state?

Louisiana Timber Supply Study

To answer these questions, a timber supply model was employed that could reasonably estimate realistic, attainable, "potential" economic softwood timber supplies in Louisiana in the future. In this study, potential timber supply is a function of the resource base in Louisiana and the management of that resource in the future. As such, the potential long-term timber supply is not a function of existing stand conditions and yields, but rather of the annual yields that could be sustained in the future by economically efficient methods of stand management. Indeed, the model is based on the premise that long-term supply is primarily a function of the amount of productive characteristics of the land available for growing timber in the state, the management intensity and types of management practices used in growing timber on these lands, and the timber yields and costs corresponding to these levels of management intensity and management practices. Such a model would provide estimates of equilibrium quantity and price for the future in Louisiana, given various assumptions regarding the size and productivity of the land base, ownership objectives, factor costs, and product prices. Further, it would indicate how much land and what kinds of management practices would be needed to attain these levels of supply.

DEVELOPMENT OF THE LOUISIANA SOFTWOOD TIMBER SUPPLY MODEL

Timber Supply Model

GASPLY, a computer program developed by Robinson et al. (1978), was used to assess the long-term pine timber supply potential in Louisiana. The general methodology employed by GASPLY was originally developed by Vaux (1973) for a supply study in California and subsequently expanded and refined by Montgomery et al. (1975) for a supply study in Georgia. Hickman and Jackson (1981) employed the methodology in their analysis of the East Texas timber market, as did Bullard et al. (1984) for their analysis in Mississippi. Hyde (1980) elaborated on the theoretical foundations of this approach to studying long-run timber supply in his book, *Timber Supply, Land Allocation, and Economic Efficiency*. The following description of the methodology and procedures utilized in this study for the construction of long-term softwood timber supply curves for Louisiana is derived from these authors.

The supply curves developed in this study were constructed on the assumption that landowners would apply economic efficiency criteria in making timber management and harvesting decisions in the future. That is, a forest landowner's objective is to maximize the present value of timber production, or the difference between future revenues and management costs, all expressed in today's dollars.

Generally, present net values per unit of output were calculated for every management regime specified for given acreages of forest land. These acreages, together with their associated management regimes, costs, and yields, were then assembled into long-term timber supply curves. These curves represent the annual quantities of timber that producers would make available to the public at various stumpage price levels in the future.

More specifically, the procedures for developing timber supply curves in this study included describing the forest land base according to ownership, productive capacity, and suitability for growing pines (or forest types); establishing different levels of management intensity, as well as specifying alternative management regimes for each level of intensity; estimating timber yields associated with different management levels and regimes on acreages of various productive capacities and ownerships; and, finally, determining the costs and present net values associated with these management levels and regimes. Supply curves were then constructed for all relevant combinations of ownerships, productive capacities, and forest types after the yields, production costs, and present net values associated with the management levels and regimes were estimated.

Management regimes for different levels of management intensity were specified for various combinations of ownerships, productive capacities, and current forest types (owner/productivity/forest types). In constructing the long-term timber supply curves, only one management regime could be used at any given price for each owner/productivity/forest type, since two different levels of management or two different management regimes for a given level of management cannot be utilized on the same site. Consequently, at any given price, that regime having the highest land expectation value (highest present net value) was used in determining the annual harvest associated with a particular owner/productivity/forest type combination.

To find the annual harvest forthcoming at each price level, the acreages associated with each owner/productivity/forest type combination were multiplied by the average annual yield (total yield/rotation age) corresponding to the appropriate management regime (chosen according to the highest present net value) to determine the total annual yield contributed from each combination. These totals were arrayed by unit volume cost and the output then summed over all owner/productivity/forest type combinations to determine the total annual production that could be expected at each given price. Each stumpage price level leads to a different ordered array of unit costs and average annual yields. A supply curve was formed by plotting these annual yields against the increasing price levels.

The supply curve developed under these procedures is consistent with economic theory (Hyde 1980). Supply is generally defined as the quantity of output producers would be willing to place on the market at different prices. In this study, the quantity variable is annual harvest (growth) in some future time period; the producers are forest landowners growing timber, presumably to be sold; and the prices are the real prices (prices excluding inflation or deflation) of stumpage in some future time period.

The timber supply schedule is expected to be positively sloped. At low market prices, the management of some acreages may not generate positive net returns, that is, returns may not be sufficient to pay off all management costs, including capital costs. Thus, only yields from acreages with at least one regime with positive returns, including returns equal to zero, are used in determining output at each given price level. As prices increase, supply is expected to increase for two reasons. First, higher prices should justify more intensive levels of management which should increase productivity. Second, higher prices should justify the long-term management of what were submarginal timberlands under lower prices. Thus, both the size of the commercially operable timberland base and its productivity should increase as prices increase.

Theoretically, the point of intersection between the supply curve and a relevant demand curve provides the expected future equilibrium quantity of timber consumption and the equilibrium price at which that quantity will be sold. The equilibrium quantity is provided only from acreages of forest land having at least one management regime exhibiting a positive net return. Thus, consistent with economic theory, this acreage includes acreage providing the last additional increment of annual harvest at which the market equilibrium price is just equal to the unit cost of supplying timber from that acreage.

A number of assumptions are implicit in the long-term future timber supply curves derived from the general methodology and procedures employed in this study. The timber market is assumed to be competitive. Aside from the typical product distribution of a forest stand (e.g., pulpwood, saw logs, veneer logs, chip-n-saw logs, and poles), the timber product is assumed to be homogeneous. Thus, the market is not differentiated in this way. Further, a large number of producers is assumed. In effect, any one producer cannot significantly affect price. These producers manage their forest lands to maximize their returns to forestry and do so under reasonable and informed future price expectations. Land uses are expected to be static; that is, all current forest acreages will be available for forestry in the future. Further, the analysis assumes that existing forest management practices and applied technology will be used in the future.

Management Levels and Regimes

Management regimes differ by the level, or intensity, of management. Three management levels identified in this study were plantation management, natural stand management, and custodial management. Plantation management, the most intensive form of management, relies on relatively expensive, artificial means of regenerating stands. Natural stand management relies on natural means of regenerating future stands, largely by seed trees or through shelterwood systems. This management level is considered less intensive than plantation management even though intermediate stand treatments such as TSI and thinning may be applied. Custodial management is the least intensive form of management; indeed, it is a passive form of management. The only treatment applied to stands managed by custodial management is a final harvest; no deliberate provisions are made for regeneration, release, density control, or protection.

Forest stands managed under one of the three levels of management intensity can be managed by various management regimes, where a management regime is characterized by the regeneration methods, silvicultural treatments, and harvesting practices employed and their timing. Thus, the individual components of a regime can be classified according to their timing of application in the life of a stand—stand establishment, intermediate treatments, and final harvest.

The management regime(s) used to manage forest stands will vary by forest type, as well as by site productivity, physiographic site class, and ownership. Since this study concentrated on the pontential long-term pine supply, only pine was featured. Further, as slash pine is most suited to only a small geographic location in Louisiana, the loblolly-shortleaf pine type was assumed adaptable to those sites. Management regimes were specified for sites currently containing pine, oak-pine, or upland hardwood—all sites in pine or potentially convertible to pine in Louisiana.

The forest land base in the state is classified by the USDA Forest Service according to site productivity. In their classification, productivity is based on the potential average annual cubic foot growth rate of a fully stocked natural stand on a given site. In this study, high sites were assumed to have an average annual productivity potential greater than 120 cubic feet per acre per year, medium sites 50–120 cubic feet per acre per year, and low sites 20–50 cubic feet per acre per year.

Three ownership classes were identified. These were public ownership, industrial (forest products companies) ownership, and nonindustrial private forest land (NIPF) ownership.

A total of 81 management regimes were specified for use in developing the long-term timber supply curves in this study. Three management regimes were specified for each combination of one of three forest types, on one of three levels of site productivity, managed by one of three ownership classes, employing one of three levels of management intensity. The specification of these management regimes was based on three general considerations. Since this study was concerned with the economic long-term softwood timber supply potential, an effort was made to include regimes that represented the economically optimum management regimes for a given site index under current price and cost expectations. This was done for both natural and planted stands. Further, relatively short, medium, and long rotations and zero thinnings to two thinnings were specified for each site class, ownership class, and level of management intensity. Finally, the regimes were specified to represent current practice, currently recommend actions, or possible future practice. The management regimes were also based on discussions with industry, consulting, and public foresters and on those used in similar supply studies in the South (Bullard et al. 1984, Hickman and Jackson 1981, Montgomery et al. 1975).

At any given price, the economically optimum management regime of the nine specified for an ownership/productivity/forest type combination was chosen for determining average annual yield at that price. That is, the economically optimum regime was picked from one of three—plantation, natural or custodial regimes. The economically optimum regime could vary as price increased, from custodial regimes exhibiting lower levels of costs and yields, to natural stand regimes with higher costs and yields, to plantation management regimes usually exhibiting the highest costs and yields. At higher price levels, the higher yields and higher valued products expected under the more intensive levels of management were expected to off-set the higher cost levels.

The plantation management regimes used in the study are presented in table 3. Three regimes are specified for each ownership and site class combination. In all cases, site preparation and planting occur immediately after final harvest. Up to 5 prescribed burns are specified, the first starting at age 13. The time period between prescribed burns on public and nonindustrial private forest lands is 10 years and on industry lands is 7 years. Rotations tend to be shorter for industry lands and longer for public lands. All public and nonindustrial private forest land regimes contain at least one commercial thinning while some industry regimes contain no thinnings. The rationale is that public and nonindustrial private forest landowners tend to have longer rotations and sell

Table 3.—*Assumed pine plantation management regimes in Louisiana, by ownership and site class*

Treatment	Public									Industry									Nonindustrial private								
	High site			Medium site			Low site			High site			Medium site			Low site			High site			Medium site			Low site		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	Stand age																										
Site preparation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Planting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prescribed burn																											
1	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
2	23	23	23	23	23	23	23	23	23	20	20	20	20	20	20	20	20	20	23	23	23	23	23	23	23	23	23
3	33	33	33	33	33	33	33	33	33		27	27		27	27	27	27	27		33	33		33	33	33	33	33
4		43	43		43	43		43	43			34			34			34			43			43			43
5			53			53			53																		
Commercial thinning																											
1	25	20	20	25	20	20	25	25	20		15	15		15	15		20	20	20	15	15	20	15	15	30	20	25
2		35	35		35	35		35	40		20	22		20	22			30		25	25		25	25		30	35
3			50			50						29			29						35			35			
Final harvest	40	50	60	40	50	60	40	50	60	25	30	40	25	30	40	30	30	40	30	35	45	30	35	45	35	40	45

sawtimber, while some forest products companies might convert to shorter pulpwood rotations, rotations with no thinnings.

In all cases it was assumed that 850 trees per acre are planted and that commercial thinnings are conducted to a residual basal area of 80 square feet per acre.

The natural even-aged stand management regimes used in the study are presented in table 4. A site preparation burn is conducted two years after the initial harvest and TSI is conducted at age 6 to release the young stand from unwanted vegetative competition. A precommercial thinning is conducted at age 10 to remove residual seed trees and reduce the number of stems per acre. Natural stands are periodically prescribed burned. The same sequence of prescribed burns as that used in pine plantations is assumed. As in plantation management, industry is assumed to employ the shortest rotations and public ownerships the longest. Commercial thinnings are also assigned; however, the first thinning usually occurs at least 5 years later than in plantations. At least 10 years separates individual thinnings.

Custodial management regimes, as might currently be found on many nonindustrial private forest lands, represent a passive form of management. Periodic harvests are conducted at ages 45 to 60. Given the low level of management associated with custodial regimes, mixed pine-hardwood stands are expected to develop.

Timber Yields

An associated set of yields must be estimated for each management regime specified (tables 5–7). Higher yields are expected under the options with the longer rotation ages, although that is not necessarily true of the average annual yield, or mean annual increment. Higher yields also are expected under more intensive levels of management and on higher site classes.

The site classes used for construction of the yield tables are based on USDA Forest Service Survey reports classifying the commercial forest land base according to site productivity, where site productivity is measured by the potential average annual growth in cubic feet capable of being grown under natural stand conditions. In most growth-and-yield models used for predicting yields, however, measures of site productivity are based on site index. Consequently, site indexes corresponding to the site productivity classes are assumed.

Plantations.—A growth-and-yield model for thinned loblolly pine plantations developed by Hafley and Buford (1985) was used to predict plantation thinning and final harvest yields (table 5). On all sites and ownerships, a planting of 850 trees per acre with 80 percent survival after the first year was assumed. A row-low thinning option, with every fifth row removed in the first pass and thinning from below in the second, was assumed in the first thinning. A selection

Table 4.—*Assumed natural even-aged pine management regimes in Louisiana, by ownership and site class*

Treatment	Public									Industry									Nonindustrial private								
	High site			Medium site			Low site			High site			Medium site			Low site			High site			Medium site			Low site		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	Stand age																										
Site preparation burn	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
TSI	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Precommercial thinning	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Prescribed burn																											
1	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
2	23	23	23	23	23	23	23	23	23	20	20	20	20	20	20	20	20	20	23	23	23	23	23	23	23	23	23
3	33	33	33	33	33	33	33	33	33	27	27	27	27	27	27	27	27	27	33	33	33		33	33		33	33
4		43	43		43	43		43	43		34			34	34		34	34			43			43			43
5			53			53		53	53		41							41									
Commercial thinning																											
1	25	20	25	25	20	25	25	20	20		25	20		25	20		30	30		25	20		25	20		25	20
2		30	35		30	35		30	30		30	30		30	30			40			30			30			30
3			45			45																					
Final harvest	40	50	55	40	50	55	40	55	55	30	35	40	30	35	40	30	40	50	30	40	50	30	40	50	30	40	50

option was assumed in later thinnings. Thinnings were conducted to a residual basal area of 80 square feet. All final harvests were clearcuts with site preparation and planting immediately following. The low, medium, and high sites were represented by site indexes (base age 25) of 50, 60, and 70, respectively.

Natural Stands.—The growth-and-yield model used for predicting yields for natural stand management regimes was developed by Murphy (1983) for predicting merchantable and sawtimber volumes for natural even-aged stands of loblolly pine in the West Gulf Region (table 6). Initial stand conditions (basal area) at some specified age had to be assumed to use the model; consequently, a total of 130 square feet of merchantable basal area was assumed at age 20, with 30 square feet in sawtimber basal area. These conditions presuppose adequate regeneration, a precommercial thinning at age 10 to improve stand density and spacing, and full stocking at age 20. Thinning from below was assumed for all thinnings. As in plantations, thinnings were conducted to a residual basal area of 80 square feet and a clearcut was used in the final harvest. Although the latter was assumed in determining final harvest yield, it is expected that a few seed trees would be left after each harvest to ensure adequate regeneration. The site indexes (base age 50) assumed for the low, medium, and high sites were 65, 80, and 95, respectively.

Custodial Stands.—Timber yields of custodial stands (table 7), yields resulting from a more passive form of management as practiced by most nonindustrial private forest landowners, do not result from the employment of deliberate management practices. Stands are clearcut or high-graded and the resulting stands evolve naturally, with no intentional input or treatments applied by their owners. The custodial yields used in this study were based on average timber characteristics of the better stocked natural stands in North Carolina and Eastern Virginia reported by Knight (1978). Knight reported total cubic foot volume production at various ages on good, medium, and poor sites.

In this study, pine sites were assumed to contain 75 percent pine stocking; oak-pine sites were assumed to consist of 40 percent pine stocking; and upland hardwoods were assumed to contain 10 percent pine stocking. The percentages used account for both the pine stocking component and for the possibility of lower stocking than was assumed in Knight's report. As a result, average annual pine production is assumed to range from just below 2.6 cubic feet per acre on upland hardwood stands on low sites harvested every 60 years to 53.0 cubic feet per acre on pine types on high sites harvested every 45 years. The pine component of these stands was assumed to contain 70 percent sawtimber and 30 percent pulpwood.

Table 5.—*Assumed yields associated with pine plantation management regimes, by site class and management regime*

Site class regime	Thinning			Final harvest	Total	Average annual	Rotation age
	1	2	3				
	---------- Ft^3 ----------						*Years*
Public							
High site							
Regime 1	2540	....	....	4275	6815	170.4	40
Regime 2	2000	1710	....	3818	7528	150.6	50
Regime 3	2000	1710	940	3509	8159	136.0	60
Medium site							
Regime 1	1730	....	....	3538	5268	131.7	40
Regime 2	1280	1270	....	2939	5489	109.8	50
Regime 3	1280	1270	510	3100	6160	102.7	60
Low site							
Regime 1	1100	....	....	2611	3711	92.8	40
Regime 2	1100	620	....	2213	3933	78.7	50
Regime 3	690	1050	....	2399	4139	69.0	60
Industry							
High site							
Regime 1	....	....	....	4486	4486	179.4	25
Regime 2	1130	830	....	3384	5344	178.1	30
Regime 3	1130	1120	780	3608	6638	166.0	40
Medium site							
Regime 1	....	....	....	3384	3384	135.4	25
Regime 2	620	680	....	2773	4073	135.8	30
Regime 3	620	900	570	2799	4889	122.2	40
Low site							
Regime 1	....	....	....	2917	2917	97.2	30
Regime 2	690	....	....	2356	3046	101.5	30
Regime 3	690	770	....	2105	3565	89.1	40
Nonindustrial private							
High site							
Regime 1	2000	....	....	3519	5519	184.0	30
Regime 2	1130	1500	....	3507	6137	175.3	35
Regime 3	1130	1500	990	3423	7043	156.5	45
Medium site							
Regime 1	1280	....	....	2924	4204	140.1	30
Regime 2	620	1180	....	2805	4605	131.6	35
Regime 3	620	1180	680	2767	5247	116.6	45
Low site							
Regime 1	1100	....	....	2349	3449	98.5	35
Regime 2	680	770	....	2105	3555	88.9	40
Regime 3	1100	620	....	2072	3792	84.3	45

Management Costs

The cost of supplying timber had to be estimated for each of the three management regimes associated with each combination of ownership, forest type, site class, and level of management. As such, costs were established for all recognized forest management practices, including such practices as site preparation, planting, TSI, and precommercial thinning.

The costs of various forest management practices corresponding to plantation, natural, and custodial stands are presented in table 8. While these figures do not apply in all cases, their reasonableness is based on a number of sources, including a survey of industrial, public, and consulting foresters in Louisiana, cost studies (Guldin 1983, Moak et al. 1983, Kronrad et al. 1984), and other timber supply studies in the South (Bullard et al. 1984, Hickman and Jackson 1981, Montgomery et al. 1975).

Costs are assumed to vary for a given level of management by ownership and by forest type. Costs vary by ownership for a number of reasons. One of these is the typical scale of application. Forest industry tends to operate on large tracts, while contractors servicing nonindustrial private forest landowners often operate on small, scattered tracts. As a result, these contractors tend to have more "dead" time. Further, contract prices of practices employed on nonindustrial private forest lands, as well as some on public forests, include

Table 6.—*Assumed yields associated with natural even-aged pine management regimes, by site class and management regime*

Site class regime	Thinning			Final harvest	Total	Average annual	Rotation age
	1	2	3				
	----------			*Ft³*		----------	*Years*
Public							
High site							
Regime 1	1410	....	....	3569	4979	124.5	40
Regime 2	800	900	....	4124	5824	116.5	50
Regime 3	1410	830	710	3303	6253	113.0	55
Medium site							
Regime 1	1200	....	....	3037	4237	105.9	40
Regime 2	680	770	....	3510	4960	99.2	50
Regime 3	1200	710	600	2811	5321	96.7	55
Low site							
Regime 1	1020	....	....	2584	3604	90.1	40
Regime 2	580	650	....	3327	4557	82.9	55
Regime 3	580	650	....	3327	4557	82.9	55
Industry							
High site							
Regime 1	....	....	....	3886	3886	129.5	30
Regime 2	1410	400	....	2491	4301	122.9	35
Regime 3	800	900	....	3067	4767	119.2	40
Medium site							
Regime 1	....	....	....	3307	3307	110.2	30
Regime 2	1200	336	....	2119	3655	104.4	35
Regime 3	680	770	....	2609	4059	101.5	40
Low site							
Regime 1	....	....	....	2814	2814	93.8	30
Regime 2	1440	....	....	2221	3604	90.1	40
Regime 3	1440	550	....	2345	4335	86.7	50
Nonindustrial private							
High site							
Regime 1	....	....	....	3886	3886	129.5	30
Regime 2	1410	....	....	3569	4979	124.5	40
Regime 3	800	900	....	4124	5824	116.5	50
Medium site							
Regime 1	.....	....	....	3307	3307	110.2	30
Regime 2	1200	....	....	3037	4237	105.9	40
Regime 3	680	770	....	3510	4960	99.2	50
Low site							
Regime 1	....	....	....	2814	2814	93.8	30
Regime 2	1020	....	....	2584	3604	90.1	40
Regime 3	580	650	....	2986	4216	84.3	50

Table 7.—*Assumed pine yields associated with custodial management regimes, by site index*

Site class regime	Pine			Oak-pine			Upland hardwood		
	Final harvest	MAI[1]	Rotation age	Final harvest	MAI	Rotation age	Final harvest	MAI	Rotation age
High site	----- *Ft³* -----		*Yrs*	---- *Ft³* -----		*Yrs*	----- *Ft³* ----		*Yrs*
Regime 1	2385	53.0	45	984	21.9	45	236	5.2	45
Regime 2	2486	49.7	50	1050	21.0	50	248	5.0	50
Regime 3	2565	46.6	55	1102	20.0	55	258	4.7	55
Medium site									
Regime 1	1717	38.2	45	722	16.0	45	174	3.9	45
Regime 2	1807	36.1	50	784	15.7	50	186	3.7	50
Regime 3	2565	34.0	55	840	15.3	55	197	3.6	55
Low site									
Regime 1	1234	24.7	50	634	12.7	50	139	2.8	50
Regime 2	1294	23.5	55	670	12.2	55	146	2.7	55
Regime 3	1335	22.2	60	700	11.7	60	153	2.6	60

[1]Mean annual increment (average annual yield).

Table 8.—*Assumed costs of managing plantation, natural, and custodial pine stands in Louisiana, 1985*

Item	Pine			Upland hardwood		
	Public	Industry	Nonindustrial private forest	Public	Industry	Nonindustrial private forests
	Dollars					
			Plantation			
Site preparation	90	70	85	105	85	100
Planting (hand)	50	50	50	53	53	53
Prescribed burning	5	4	5	6	5	6
Commercial thinning	10	10	14	11	11	15
Final harvest	5	5	9	5	5	9
			Natural			
Site preparation burning	7	4	7	7	4	7
TSI	40	25	40	60	45	60
Precommercial thinning	40	30	40	55	45	55
Prescribed burning	5	4	5	7	6	7
Commercial thinning	10	10	14	11	11	15
Final harvest	16	16	20	18	18	22
			General			
Property taxes	1	1	1	1	1	1
Annual management	1	2	1	1	2	1

a profit margin for the contractor, a margin not directly accounted for in the cost of the practice for industrial forests. These margins are usually included in the annual overhead costs, or annual per acre "management costs", of forest industry and public agencies. Nonindustrial private forest landowners must often pay consulting fees, both for visiting a tract and recommending treatments, as well as for later supervision or inspection of the applications of prescribed treatments. Again, these costs are often included in annual overhead on industrial and public lands. Finally, costs may be higher for public agencies than for industry because public agenices are often more restricted in practice application and treatment supervision. Contractors might expect higher per unit prices for both reasons.

Costs are also assumed to vary by existing forest type. Since potential long-term pine supply is the focus of this study, all sites currently in pine or potentially convertible to pine form the land base under study. Similar management regimes for a given ownership, site productivity, and management level are specified for each of these forest types. Further, the same pine timber yields for a given management regime are expected. The yields on upland hardwood sites will come only at higher costs of forest management, because of hardwood competition problems. Practices such as site preparation, TSI, precommercial thinning, and prescribed burning will necessarily have to be more intense on upland hardwood sites than on pine sites if yields on each are expected to be equal for a given management regime.

Annual overhead costs include property taxes for industrial and nonindustrial private forest lands; road maintenance, staff, and management practices supervisory costs of industrial lands; and forest protection, research, education, management services, and road maintenance on public lands. These costs are all fixed and are based on overhead costs used in other similar supply studies (Bullard et al. 1984, Hickman and Jackson 1981, Montgomery et al. 1975). Annual overhead costs were assumed to be $3.00 per acre for public lands and $2.00 per acre for private.

Interest rates used for compounding and discounting costs and returns reflect assumed long-term real capital costs, costs in which the effect of inflation has been removed. These rates, used by Bullard et al. 1984, Hickman and Jackson (1981), and Montgomery et al. 1975, are 3 percent for the public, 4 percent for the industrial, and 5 percent for the nonindustrial private forest landownership classes. These rates reflect historical rates of growth in real GNP, prime interest rates, and expected higher time preferences for money and income of the nonindustrial private forest landownership class.

Land costs are excluded from the analyses. Two assumptions excluded alternative land uses and land sales or exchanges from the models. First, all existing commercial forest lands are expected to remain available for timber production in the future and, second, forest land exchanges among different ownership groups are expected to be negligible.

Timber Demand

Two demand curves were assumed, each with a different price elasticity of demand, but both based on the assumption of demand doubling over the next 50 years. Price elasticities of demand reflect the position and slope of the demand curve, the lower the elasticity (measured in absolute values), the steeper the demand curve. More specifically, the price elasticity of demand measures the percentage change in quantity demanded resulting from a one percent change in price. A demand curve with a low elasticity coefficient implies that quantity demanded is relatively insensitive to changes in price while a high coefficient implies that quantity demanded is relatively sensitive to changes in price.

Two different demand assumptions were employed in this study because various authors have presented different elasticity assumptions—Bullard et al. (1984) and Robinson et al. (1981) at .50, Hickman and Jackson (1981) at .073, and Montgomery et al. (1975) at .13. Thus, the price elasticity of demand for stumpage tends to be relatively inelastic, i.e., tends to have a low coefficient of elasticity. The two elasticities used in this research were .10 and .50, the first being highly inelastic and the other relatively more elastic, although still inelastic.

RESULTS

A modified version of GASPLY was used to assess the potential long-term softwood timber market in Louisiana and to evaluate the impacts of various resource, economic, and management assumptions on long-term supplies and prices. Assumptions, or different scenarios analyzed, included:

1. No restriction on acreages, prices, or management practices employed (BASE),
2. Interest rates doubled to 6, 8, and 10 percent (DOUBLE INTEREST),
3. Nonindustrial private forest (NIPF) land restricted to custodial management (CUSTODIAL),
4. Nonindustrial private forest (NIPF) land acreage reduced to exclude forest ownership holdings of less than 10 acres (ACRE10), 20 acres (ACRE20), and 40 acres (ACRE40), and,
5. Potential pine commercial forest land acreage reduced to exclude upland hardwood sites (HARDWOOD).

Recent production levels and stumpage prices in Louisiana are used as a basis for evaluating future real softwood prices (prices excluding inflation) and timber output resulting from the scenarios listed above. Average annual production in Louisiana over the 5-year period 1980–84 was 469.6 million cubic feet, while the weighted average softwood price over the same time period was $.394 per cubic foot, or $394 per thousand cubic feet (MCF).

Base

Figure 1 shows future long-term softwood timber supply (BASE) at various prices if no restrictions on acreages, prices, or management practices were assumed and if forest landowners and managers employed economic efficiency criteria in their decision making processes. The optimal management regime for every owner/site/forest type combination at each price level can be selected from one of three plantation, natural even-aged, or custodial management regimes. The potential long-term sustained yields associated with each price along the supply curve are associated with all the optimal management regimes having a positive present net value. The supply curve assumes discount rates of 3, 4, and 5 percent for public, industrial, and nonindustrial private forest landowners, respectively.

Louisiana forests potentially manageable under pine management regimes would not be deliberately managed at prices less than $90 per MCF. Some forest lands would be managed by custodial management regimes at prices between $90 and $120 per MCF, and all forest lands currently in pine or potentially convertable to pine could be managed by either plantation or natural even-aged management regimes at prices equal to or greater than $210 per MCF.

The supply curve becomes highly to completely inelastic (nearly vertical) at prices above $210 per MCF.

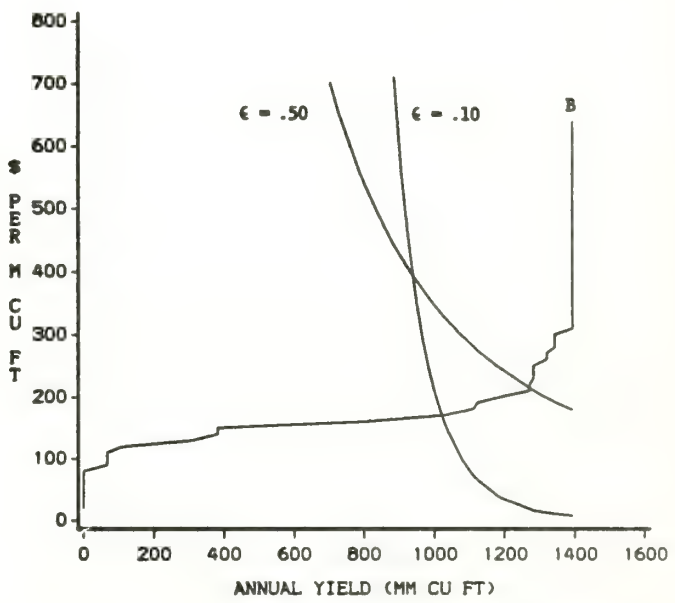

Figure 1.—*Estimated long-term demand, supply, and equilibrium conditions of the Louisiana softwood timber market: BASE (B) supply case.*

This implies that annual sustained yield could not be increased significantly beyond this value. Louisiana's forest lands would reach their limits of economic production at prices of about $320 per MCF. This limit is estimated to be about 1393 million cubic feet annually, given the prices, costs, management regimes, discount rates, acreages, and other assumptions used in this study. Positive price changes beyond $320 per MCF would generate relatively little to no response in supply.

Three sets of long-term equilibrium prices and annual production rates are presented in figure 1. Two sets are associated with the two demand elasticity assumptions. Both demand curves assume a doubling of demand over the next 50 years. One demand curve assumes an elasticity of .10 and the other .50 (in absolute values). The third set of equilibrium values are based on the assumption that softwood stumpage prices will not change in real value over the next few decades.

The equilibrium price and annual rate of production under the highly inelastic demand curve, that with an elasticity coefficient of .10, are $170 per MCF and 1023 million cubic feet. This level of annual production would come from 4.12 million acres of plantations, 2.46 million acres of natural even-aged stands, and 1.19 million acres managed by custodial regimes. Approximately 1.44 million acres would not be managed at all for continuous softwood production. The unmanaged acreages would come from the current upland hardwood sites and low productivity pine sites. Comparing these results to the average annual production rates and price levels experienced in the period 1980–84, production could be more than doubled at about two-fifths the real prices of those recently experienced.

At an elasticity of .50, equilibrium price and quantity would be $215 per MCF and 1270 million cubic feet. At this price, about one-half of the 9.2 million acre land base used in this study would be managed with plantations and the other one-half would be in natural even-aged stands. Even with this demand curve, potential production would be considerably higher and real prices considerably lower than their corresponding values in the period 1980–84.

Although potential changes in future prices and quantities are favorable under both demand scenarios, the management practices employed in producing the equilibrium quantities under the two are significantly different. For example, under the curve with an elasticity of .50, all 9.20 million acres used in this study would be managed—half by plantations and half by natural even-aged stands. Under the other demand curve, about 16 percent of the acreage would not be managed at all and 13 percent would be managed by custodial management. Thus, although annual production could more than double at significantly lower prices under both demand assumptions, the choice of future demand scenarios by forest planners and public policy makers is crucial for management planning and decisionmaking for the future.

If real prices were to remain unchanged over the next 50 years, annual long-term softwood timber production could be 1393 million cubic feet, the limit of economic production given all assumptions in the analysis (fig. 1). This implies that pine production in Louisiana could almost triple at current real price levels. All but .072 million acres would be managed with plantations. Only the poorer sites would be managed by a non-plantation management system, and these would be managed by natural even-aged regimes.

The results of the BASE analysis indicate that annual production could be increased at substantially lower prices in Louisiana. This is not unexpected, however, since the commercial forest land base in the state is highly productive, with the potential of economically producing much more than it currently does. Nevertheless, the results seem suspect when the likelihood of output doubling at two-fifths to one-half recent price levels in the state is considered. A number of factors may be influencing the results. Since few restrictions were placed on the supply model, such influences as periodic droughts, pest and disease infestations, and minimum operable tract sizes were not taken into account. These would impact the annual production expected from the commercial forest land base in the state, as well as the size of the land base for producing timber. Another influence on the BASE results could be that the required real rates of return are too low.

Double Interest Rates

While the use of real discount rates of 3, 4, and 5 percent for public, industrial, and nonindustrial private forest landowners, respectively, has been justified by previous authors (Hickman and Jackson 1981 and Montgomery et al. 1975), these rates might seem too low for others, particularly in the current economic climate where real rates of return and costs of borrowing capital tend to be high. Another supply curve (DOUBLE INTEREST) was developing using rates of 6, 8, and 10 percent, or double the base rates (fig. 2).

Equilibrium prices and quantities under the two demand scenarios are approximately the same, about $429 per MCF and 905 million cubic feet of annual production. The long-term equilibrium price is slightly higher and annual production just under double their corresponding values in 1980–84. Thus, even at double the required real rate of return for forestry investments, production could almost double without requiring significantly higher real prices. About one-

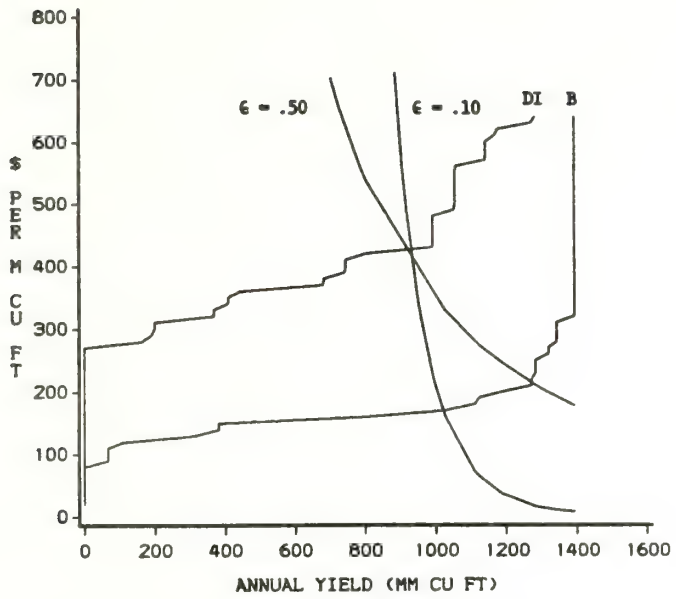

Figure 2.—*Estimated long-term demand, supply, and equilibrium conditions of the Louisiana softwood timber market: BASE (B) and DOUBLE INTEREST (DI) supply cases.*

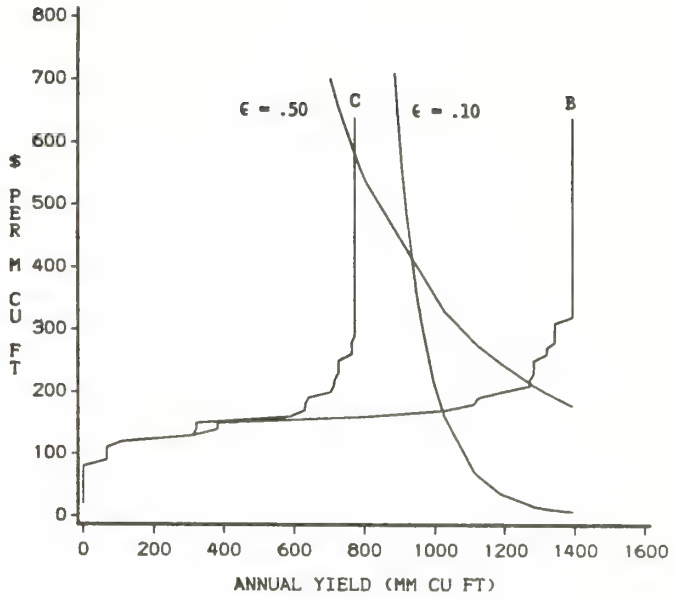

Figure 3.—*Estimated long-term demand, supply, and equilibrium conditions of the Louisiana softwood timber market: BASE (B) and CUSTODIAL (C) supply cases.*

fifth of the commercial forest land would be in plantations on high sites under the new interest rate assumptions. Most of these plantations would be found on industrial lands; none would be found on nonindustrial private forest land ownerships.

Custodial Management Restrictions

In developing the potential long-term timber supply function, it was assumed that commercial forest landowners would choose economically optimum management regimes (from those specified in the procedures section) at various price levels. While this would not necessarily be true of industrial landowners and public agencies, it would be even less true of nonindustrial private landowners who for a number of reasons might not be interested in managing their forest lands primarily for the purpose of timber production.

A scenario was developed in which the management of nonindustrial forest lands was limited to custodial management regimes, those under which harvests are conducted periodically but no management practices are employed to promote pine reproduction, survival, or productivity. As such, approximately 53 percent of the commercial forest land used in the study was affected.

The decrease in supply (CUSTODIAL) resulting from this restriction was significant (fig. 3). Indeed, the limit of annual production decreased from 1393 million cubic feet under the BASE assumptions to 772 million cubic feet, a 45 percent decrease. These results confirm the importance of the nonindustrial private forest landowner and the impact that this owner's current and expected management objectives and practices can have on future timber supplies and prices.

Relative to recent rates of production, the quantity of timber supplied in the future could not be doubled at reasonable real price levels if the majority of this ownership class were to continue managing their forest lands by custodial regimes. Indeed, as can be observed from figure 3, the highly inelastic demand curve (.10) does not intersect the new supply curve at any reasonable price level. The more elastic demand curve (.50) intersects the new supply curve at a price of $582 per MCF and 772 million cubic feet. Thus, depending upon the demand scenario assumed, either future demand for softwood timber from Louisiana's current commercial forest land base will not be met or demand will be met at significantly higher real prices. In either case, production could not be expected to double.

Changes in the Commercial Timberland Base

The size of the commercial timberland base, a finite physical constraint, influences potential timber supply in the future. Thus, estimates of the commercial timberland base are required.

The Forest Service defines commercial timberland as forest land capable of producing at least 20 cubic feet of industrial wood per acre per year and not withdrawn from timber production by statute or adminis-

trative regulation; the minimum acreage requirement is 1 acre (USDA Forest Service 1982). Inaccessible and inoperable areas are included.

Although the Forest Service definition considers 1 acre as the minimum operable tract size, Louisiana does not provide funds to regenerate tracts less than 10 acres under the federal Forestry Incentives Program. Further, minimum acreage requirements for membership in the state's Tree Farm Program is also 10 acres.

While the Forest Service considers biological components required in any definition of commercial forest land, it avoids the effects of important economic factors which vary both in time and place. Small tracts, tracts with low productivity, and tracts where regeneration may be delayed for long time periods are included as commercial forest lands under the current definition. Also, the current definition does not consider the effects of intensive management on a site, the location of available markets, or the costs of harvesting timber (Clawson 1981). Therefore, Forest Service commercial forest area statistics overestimate the economic "commercial" forest land base from which future timber supplies might come.

Problems also exist with establishing 1 acre as the minimum tract size. Many landowners hold forest land for reasons other than timber production, reasons such as recreation, aesthetics, and wildlife. Since owners with small tracts may not have the option of harvesting only part of their timber, they may not be interested in harvesting timber at all (Straka et al. 1984). Another problem is that as forest operations become more highly mechanized, fixed costs of operation increase. Diseconomies of small tract size are caused by high fixed costs being spread over fewer units of output; thus, operations having high fixed overhead costs cannot harvest extremely small tracts economically (Cubbage 1982). As more timber producers and harvesters seek to increase the efficiency of their operations through the use of advanced technology, the commercial forest land base may decline because of diseconomies of small tract size. Finally, small timber volumes produced on small tracts are more difficult to market, if they are marketable at all (Cubbage 1982). Generally, the volume on small tracts might never become part of the timber supply unless future timber prices increase.

Because of these problems, an effort was made to estimate the commercial pine forest land base in Louisiana under varying minimum tract size requirements and to address the impact these changes might have on future timber supplies. More specifically, a study was conducted to determine the distribution of forest landowners in Louisiana with tracts of various sizes, to determine the minimum tract size on which forestry consultants and harvesting contractors will operate under "normal" conditions, and to determine the potential pine commercial forest land base in Louisiana based on the minimum tract size requirements of these consultants and contractors (Allen 1985).

Three-quarters of the consultants surveyed by Allen considered 20 acres or more as the minimum pine tract sizes on which they would normally operate, one-third of the harvesting contractors considered 20 acres as the minimum, and about three-fifths of the solid wood facilities contacted specified 20 acres as their minimum. Many would operate on smaller tract sizes depending upon the total tract volume, total sawtimber volume, and tract location, among other factors.

A frequency distribution of sizes of timberland ownerships was developed from the 1984 Louisiana tax records of 35 parishes in Louisiana. The distribution included only those sites that were either in pine or could be reasonably converted to pine. Of an estimated 7.31 million acres of commercial pine forest land in the 35 parishes, 0.9 percent were in holdings of 5 acres or less, 3.0 percent in holdings of 10 acres or less, 7.6 percent in holdings of 20 acres or less, and 14.7 percent in holdings of 40 acres or less. Since forest ownership land holdings were used rather than individual tract sizes, these percentages probably underestimate the actual proportion of forest land area in tracts not meeting minimum operability limits.

Three additional timber supply curves were developed under the assumption that tract sizes of less than 10 (ACRE10), 20 (ACRE20), and 40 (ACRE40) acres are not considered commercially operable. While periodic harvests from these lands can be expected, it is assumed that they cannot be depended upon for contributing to a stable annual sustained yield. As such, approximately 3.0, 7.6, and 14.7 percent of the commercial forest land base was deducted from that used in the BASE scenario. The acreage was deducted from the nonindustrial private forest land ownership class because it would be more likely to have the smaller holdings (tracts) associated with it.

Any reduction in acreage would be expected to result in a decrease in long-term supply. And, indeed, supply (ACRE10, ACRE20, and ACRE40) decreases as the commercial forest land base decreases (fig. 4). Compared to recent prices and quantities, however, equilibrium prices decrease by a minimum of 30 percent and quantities supplied more than double when the nonindustrial commercial forest land base is reduced. Thus, supply could be substantially increased at considerably lower real prices even when small forest land ownerships are excluded from the commercial forest land base.

When compared to the BASE scenario, equilibrium prices increase and quantities decrease, although the values depend upon the demand curve assumed. Price and quantity changes are relatively unaffected under the highly inelastic demand curve (.10). Under the

other demand curve, real prices increase by as much as $62 and equilibrium quantities decrease by as much as 149 million cubic feet. Nevertheless, real prices would still be lower and quantities more than double those experienced in recent time periods.

Upland Hardwood Sites Excluded

The acreage considered in this study included upland hardwood sites under the assumption that these sites could be converted to pine stands, although at higher costs than to manage existing pine types. The success of such conversion might be questionable. As a result, a long-term pine timber supply curve (HARDWOOD) was developed under which all upland hardwood acreage was excluded from the land base which could provide the future softwood timber supply (fig. 5). This restriction resulted in a decrease of approximately 2.209 million acres from the land base, a 24 percent decrease, primarily on high and medium sites.

Equilibrium long-term real prices would decrease by as much as $75 and production increase by up to 520 million cubic feet, depending upon the demand curve assumed. Thus, long-term production could more than double that of recent years with the exclusion of upland hardwood sites from the land base.

POLICY IMPLICATIONS

The results of this study have several policy implications, and their impacts are reflected in the various prices and quantities presented in table 9. For example, the federal government and a number of southern states have various programs designed to provide forrest practices incentives to private forest landowners. Whether through cost sharing or special tax provisions, the intent of these programs is to promote forest management on commercial forest lands, particularly by the nonindustrial private forest landowner. To the extent that these programs, together with other management assistance and educational programs, promote more intensive forest land management on these ownerships, future softwood timber supplies could be more than doubled at significantly lower real prices. To the extent that these programs are reduced or unclaimed by this landowner group, Louisiana's contribution to meeting future demands at reasonable prices may not be met.

Table 9.—*Summary of long-term equilibrium softwood prices and quantities in Louisiana under various acreage, management, interest rate, and demand assumptions*

Assumption	Price elasticity of demand			
	−0.10		−0.50	
	Price/ MCF	Quantity MMCF	Price/ MCF	Quantity MMCF
BASE[1]	170	1,023	215	1,270
CUSTODIAL	.....	.....	582	772
DOUBLE INTEREST	427	932	429	905
ACRE10	174	1,027	228	1,233
ACRE20	179	1,019	245	1,185
ACRE40	196	1,007	277	1,122
HARDWOOD	319	977	354	990

[1]BASE: Interest rates of 0.03, 0.04, and 0.05 for public, industrial, and nonindustrial private landowners. Commercial forestland in pine or potentially convertible to pine equal to approximately 9.2 million acres, including pine, oak-pine, and upland hardwood forest types.

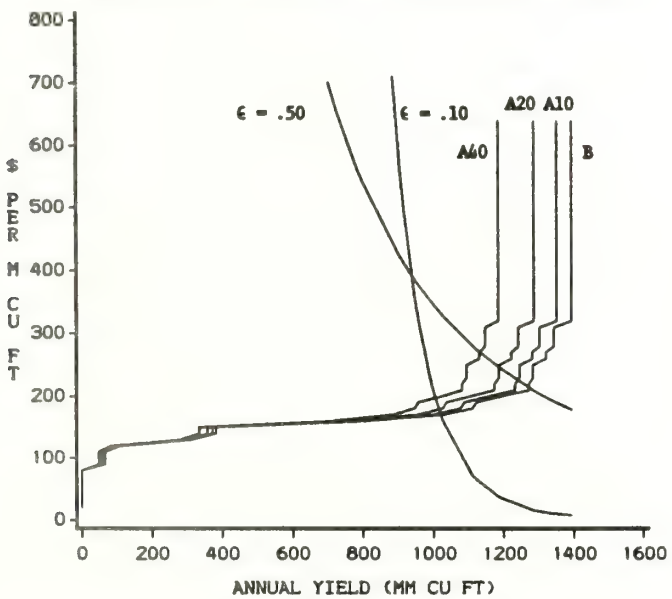

Figure 4.—*Estimated long-term demand, supply, and equilibrium conditions of the Louisiana softwood timber market: BASE (B) and ACRE10 (A10), ACRE20 (A20), and ACRE40 (A40) supply cases.*

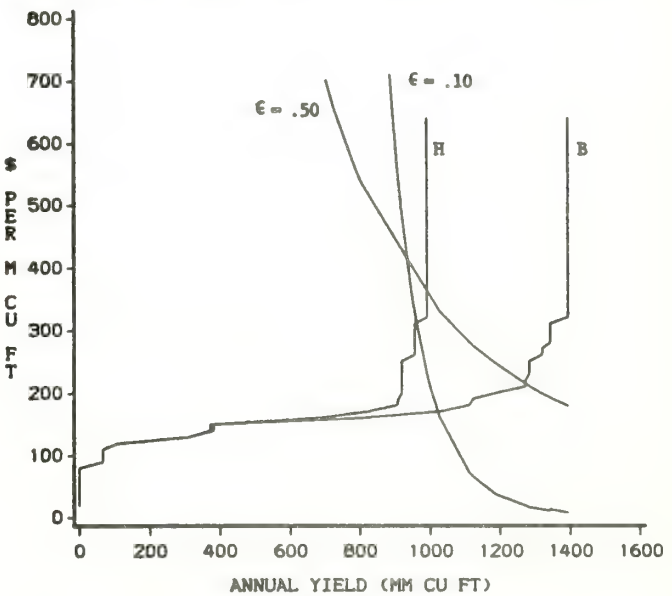

Figure 5.—*Estimated long-term demand, supply, and equilibrium conditions of the Louisiana softwood timber market: BASE (B) and HARDWOOD (H) supply cases.*

Another policy issue related to management assistance, educational programs, extension services, and incentives programs concerns the audience to which these should be directed. In Louisiana, about 80 percent of the forest landowners in the state own forty acres or less of timberland, or slightly less than 15 percent of the commercial forest land in pine, oak-pine, or upland hardwood. Should efforts promoting improved forest management practices on nonindustrial private forest lands be directed equally at all forest landowners, or should these efforts be proportional to size of forest landholdings? In other words, should the majority of the efforts be directed to the 20 percent of the landowners controlling 80 percent of this forest land base? What might the impact be on future timber supply?

A related question, although more economic in nature, is the advisability of including all reported commercial forest land in future timber supply studies. How much supply might be exaggerated depends upon the proportion of the acreage in such small tract sizes or ownership holdings that are economically inoperable. At the very least, some tracts or holdings might be too small to offer a long-term sustainable output.

The impact on long-term pine timber supply of excluding small tracts and ownership holdings of 10 acres or less (ACRE10), 20 acres or less (ACRE20), and 40 acres or less (ACRE40) was considered. Relative to the base prices and quantities, neither long-term real prices nor quantities were significantly affected. Exclusion of these tracts or landholdings did not preclude the commercial forest land base under study from doubling supply at reasonable prices. Nevertheless, the results do indicate by how much production might be overestimated in studies such as this. In this study, annual supply could be overestimated by as much as 145 million cubic feet, about a third of current production. Further, real prices in the future could be underestimated by as much as $62 per thousand cubic feet, although they would still remain significantly lower than those experienced in recent time periods.

Many pine and oak-pine sites are converting to upland hardwood forest types after harvest on many nonindustrial private forest land holdings, primarily because no deliberate regeneration practices occur on these sites. It was assumed in this study that all upland hardwood sites in Louisiana could be converted to pine sites, although at relatively higher management costs, which were probably conservatively estimated. Should these sites be converted from upland hardwood to pine? If so, at what cost? Should the forest type diversity of a region or state be significantly reduced? What would be the social, biological, and environmental costs? The exclusion of upland hardwood sites (HARDWOOD) from pine management had a greater impact on future prices and quantities relative to the BASE supply model than did excluding small ownerships (tract sizes). The remaining pine and oak-pine sites would have to be managed quite intensively for Louisiana to double supply. To do so would require significantly higher prices than those resulting from the BASE supply model.

SUMMARY AND DISCUSSION

The demand for forest products in the period 1976 to 2030 is expected to double. Softwood roundwood demand is projected to increase by about four-fifths in the same time period. However, those demands are not expected to be met at current price levels; this is particularly true for softwoods.

The domestic timber resource in most regions can support larger timber harvests for satisfying future demands. Average net annual timber growth per acre in 1976 on all ownerships was about three-fifths of that attainable in fully stocked natural stands, and in the South, the ratio was closer to three-fourths. Thus, the productive potential of the nation's forests is not being met. In the South alone, over three-fifths of the commercial timberland has opportunities for increasing timber supplies, opportunities largely on lands owned by farmers and other private ownerships.

A timber supply model was used to assess the potential long-term softwood timber supply in Louisiana. This model indicates how much forest land and what kinds of management practices would generate these levels of supply. Further, it provided estimates of equilibrium prices and quantities under the assumption of a doubling of demand over the next half decade. These results could be used in assessing the potential contribution of Louisiana's commercial timberlands to meeting the nation's future demand for forest products.

Louisiana has approximately 14.1 million acres of commercial timberland, comprising approximately 45 percent of the total land base in the state. Over 9.2 million acres are in pine, oak-pine, and upland hardwood forest types. Of the 9.2 million acres, approximately 53 percent are owned by nonindustrial private landowners, 39 percent by forest industry, and the remaining 8 percent by public agencies. Further, about 45 percent are classified as high sites, about 54 percent as medium sites, and the remaining 1 percent as low sites.

Average annual softwood production from the commercial forest land base in Louisiana in the period 1980–84 was approximately 470 million cubic feet at a price of $394 per thousand cubic feet. At this price, annual production would have to exceed 940 million cubic feet for supply to meet a doubling of demand in the future. Two primary questions were asked in this

study: Does Louisiana have the productive potential to double production and contribute to meeting future softwood demand? If so, can production be increased without adversely affecting future stumpage prices?

Potential long-term pine timber supply in Louisiana will be affected by changes in the commercial forest land base, the productive potential of the forest land, the forest type suitability of these forest lands, and ownership patterns, trends, and objectives. Future timber supply will also depend upon the management practices employed, which in turn will be affected by their costs and expected returns. These factors and others are included in the timber supply model employed in this study.

A summary of the equilibrium prices and quantities under various acreage, management, interest rate, and demand scenarios is presented in table 9. In all cases, demand was expected to double over the next half decade.

The Louisiana commercial forest resource base failed to meet the assumed doubling of demand under three supply scenarios, the CUSTODIAL, DOUBLE INTEREST, and HARDWOOD scenarios.

The assumption that all nonindustrial private forest lands would be managed by custodial management regimes (CUSTODIAL), together with an assumed price elasticity of demand of .10, resulted in the lack of an equilibrium quantity and price, at least at reasonable price levels. Even assuming a greater price elasticity of .50, the equilibrium price was greater than $582, an increase in real stumpage prices of $188. Further, quantity supplied was not doubled under these management restrictions. If Louisiana is expected to contribute to the South's role in meeting future demands for forest products, nonindustrial private forest landowners will have to contribute by practicing some minimum level of forest management. Otherwise, real softwood stumpage prices in Louisiana could be expected to increase substantially.

Doubling the interest rates (DOUBLE INTEREST) also had a considerable impact on long-term equilibrium prices and quantities. Although prices would still be below those experienced in recent time periods, equilibrium quantities would fall to below double those recently experienced. Relative to the BASE scenario, the equilibrium price more than doubled under one demand scenario and nearly doubled under the other. Equilibrium quantities decreased from 6 to 29 percent.

Excluding the upland hardwood forest type (HARDWOOD) from the commercial forest land base also impacted potential prices and quantities in the future. As with the DOUBLE INTEREST scenario, equilibrium prices would continue to fall below those of recent times, but the quantity supplied would not double under one demand scenario and would just barely do so under the other. Relative to the BASE scenario, excluding these sites from the potential softwood resource base would increase real prices by over $135 per MCF and decrease quantities supplied by as much as 280 million cubic feet, depending upon the demand assumption employed.

Does the commercial forest land of Louisiana have the productive potential to double softwood supply? Can it be accomplished at a reasonable price? The answer to both questions, given the assumptions used in the study, seems to be an undeniable yes. Whether or not that potential can be realized is another question. However, the results of this study provide a basis or standard of comparison when analyzing forest policy and resource issues related to future softwood supply.

Finally, as a word of caution, the results presented herein can hardly be interpreted as forecasts of future softwood timber supply conditions or expectations. Rather, they are estimates of upper bounds that could be economically feasible to grow and harvest from Louisiana's timberlands if timber production was the primary objective of forest landowners and managers and if they followed economically efficient management criteria.

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This study provides an assessment of the long-term softwood timber supply in Louisiana. A timber supply model uses a variety of factors including forest land potentials, ownership patterns, management practices, costs, and expected returns.

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